EDIBLE USES OF SOYBEAN PROTEIN

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INCREASED ACCEPTANCE OF SOY PROTEINS IS DUE TO QUALITIES WHICH ARE UNMATCHED: GOOD FUNCTIONAL PROPERTIES IN FOOD APPLICATIONS, HIGH NUTRITIONAL QUALITY, ABUNDANCE, AVAILABILITY, AND LOW COST.

DEFINITIONS AND METHODS OF PREPARATION

After the removal of the oil from the soybean, the remaining proteinaceous material is referred to as defatted flakes. Three basic soy protein content from 50 to over 90 %**,** namely soy flours/grits, soy protein concentrates and soy protein isolates. In addition, products such as full-fat soy flour, partially hydrolyzed soy proteins, and products based on traditional Oriental food patterns are also available in lesser volume.

NUTRITIONAL AND HEALTH ASPECTS OF SOY PROTEINS

Under conditions of normal dietary intake, properly processed soy protein ingredients are of good protein value for humans. This is particularly true when soy products are utilized in combination with other protein sources, such as meat, milk and cereal grains. The nutritional adequacy of soy protein products has been clearly demonstrated in infant formulas, where protein requirements are most critical.

Nutritional Value of Soy Protein Ingredients

Amino Acid Profile - Soy proteins contain all the essential amino acids required for human nutrition (growth, maintenance, and stress). The amino acid composition of soy proteins resembles, with the exception of the sulfur-containing amino acids (e.g., methionine), the amino acid patterns of high quality animal protein sources.

Digestibility Studies in animals and humans have demonstrated that soy proteins are comparable in digestibility to other high quality proteins such as meat, milk, fish and egg. Digestibility values for protein concentrates and isolates by humans fall in the range of 91-96%**,** which are comparable to values for milk.

Amino Acid Requirements In measuring protein quality in humans, studies conducted with young male adults showed that isolated soy protein is comparable in protein quality to milk and beef, and 80-90 % of whole egg, in spite of the fact that protein intakes were at suboptimal levels in these studies. When soy protein concentrate was fed to young men, nitrogen equilibrium based on nitrogen balance was attained with a mean daily nitrogen intake of 95 mg/kg, not significantly different from that of egg protein, 92 mg/kg. When soy protein concentrate was fed as the sole source of protein for 82 days at a daily intake of 0.8 g protein/kg, mean nitrogen balances were positive for all subjects.

These studies, and others, in which well-processed soy proteins were fed as the sole source of protein, or provided a significant portion of the daily intake, suggest that soy protein products are of high nutritional value for humans and can serve as the sole source of protein in providing nitrogen and amino acids for maintenance in adults.

Nutritional Value of Soy Proteins in Food Systems

There are important applications in which soy proteins are combined with other proteins. Three cases are especially important extension, supplementation, and vegetable protein mixtures.

Meat, Poultry and Fish - At levels of 0.6 to 0.7 g protein/kg body weight, there is no difference in N utilization between meat protein and highly-extended soy-beef blends. The effects of various meat-soy combinations on protein utilization will understandably differ, depending on whether the measurements are done at deficient or adequate levels of protein intake. Studies with young men using beef, fish and 50: 50 mixtures of beef, fish or milk, and isolate showed that the values for the three animal-soy protein mixtures equaled those of the all beef or fish controls. These studies show that soy proteins are excellent nutritionally when used with high quality animal proteins in the diet.

Dairy Products - Amino acid, vitamin and mineral fortification in certain products (e.g., milk formulas for infants, school lunch foods, and other institutionally-prepared foods) is both feasible and nutritionally sound. Using soy protein in these situations offers a great opportunity for providing meals that would otherwise not be available for reasons of cost, stability, ease of preparation, or medical considerations (e.g., hypo-allergenic infant formulations). Soy proteins are also a good source for special formulas in geriatric, hospital, and postoperative feeding by providing complete nutrition, specific caloric content, and a balance between calories contributed by protein, fat and carbohydrate.

Cereal Grains - Most applications for defatted soy flours and grits involve their combination with cereals. Their addition raises both the quantity and quality of the protein in cereal products. The quality of the protein is improved in soy-cereal mixtures because soy protein is a rich source of lysine, the first limiting essential amino-acid in most cereal proteins.

Health and Soy Protein Products

There is strong indication that soy proteins may offer positive health benefits of significant proportions.

Animal studies have demonstrated that animal protein (usually casein) is more cholesterolemic and atherogenic than vegetable protein (most frequently mentioned soy protein). In man, too, vegetable protein appears to be less cholesterolemic than animal proteins. The difference persists even in the face of high levels of saturated fat consumption.

In addition to their hypolipidemic efficacy, soy protein products have broad application in the formulation of low cholesterol, low fat, high P/S ratio foods.

Many soy protein products also contain dietary fiber. With the implications that dietary fiber may play a role in controlling blood cholesterol, in preventing colon cancer and improving glucose tolerance, diets containing soy flour, concentrate or soy fiber made from these products, merit special attention.

FUNCTIONALITY

With certain obvious exceptions, such as infant formulations, dietary wafers, breakfast cereals, and special dietary items, soy protein products are now being used primarily for their functional characteristics which are important to the manufacturer of conventional foods in process control, and in the design of convenience foods.

General Properties

Protein functionality is dependent upon the structure of the molecule. For example, the presence of both lipophilic and hydrophilic groups in the same polymer chain facilitates association of the protein with both fat and water. This results in the formation of stable oil and water emulsions when a protein dispersion is mixed with oil. The multiplicity of groups attached to the polymer chain of the protein, such as lipophilic, polar, nonpolar, negatively and positively charged groups, enables soy proteins to associate with many different types of compounds. Thus, it may adhere to solid particles and act as a binder or, when in solution, as a dispersing and suspending agent. Protein films may adhere to surfaces and, in addition, solids may be distributed and cemented together within the protein film.

These properties usually require a protein with a relatively high degree of water dispersibility. Soluble proteins are also easier to incorporate into foods. In a relatively insoluble protein, these properties can be expected to occur only to a limited degree. Although such products remain highly valuable nutritionally, they may contribute only slightly to viscosity, gel formation, emulsification, binding, adhesion, etc., or to the stabilization of emulsions and suspensions. Nevertheless, insoluble proteins do possess good water and fat absorption properties and, in that sense, they can be classified as being highly functional as well.

Briefly, an insolubilized protein essentially contains the same functional groups as the native protein, the only difference being a change in the accessibility of the reactive groups.

Formation and stability of protein-based food emulsions also depends very much on energy input. In general, the process and equipment used in making food emulsions, particularly very viscous emulsions, exert a major influence on the properties of the emulsion. While correlation between classical surfactant properties and emulsion behavior is positive in food systems, these fundamental properties of proteins are overridden by the mechanical processes used to make emulsions. These processes are achieved by the shearing, turbulence, cavitation, and mixing applied to food systems during emulsion formation.

Functionality of Soy Protein Ingredients

The ability of protein to aid the formation and stabilization of emulsion is critical for many applications in chopped, comminuted meats, cake batters, coffee whiteners, milks, mayonnaise, salad dressings, and frozen desserts.

Functional properties are not only important in determining the quality of the final product, but also in facilitating processing, e.g., improved machinability of cookie dough or slicing of processed meats.

These properties are generally attributed to the protein; however, other components in certain products may also contribute to functionality. For example, polysaccharides in soy flour and concentrate will absorb more water than an equivalent amount of protein.

Product characteristics of soy protein products can be varied by using various processing treatments. These treatments can involve the use of enzymes, solvents, heat, fractionation, and pH adjustment, or the combination of these treatments.

Knowledge of the fundamental properties of proteins is essential for understanding the basis of functionality for modifying proteins to acquire needed functions, and for predicting potential applications.

Soy Flours/Grits (untextured) - Full-fat soy flour applications include uses such as a source material for soy milk, tofu and other specialty foods, and as an economical extender for nonfat dry milk in beverages (mostly in developing countries). Also these ingredients have uses in baked goods (e.g., Europe, Israel and Latin America).

High-enzyme flours with lipoxidase activity can cause bleaching of carotenoid pigments in doughs thus producing whiter bread crumbs, and are also responsible for the generation of peroxides which strengthen gluten proteins.

For defatted soy flours and grits, functionality usually relates to water and fat absorption capacity. These properties are primarily dependent upon the degree of protein denaturation and particle size. Functionality is greatest in untoasted products, and is reduced in proportion to the degree of heat treatment. To optimize the way a soft ingredient performs in a food system, it is necessary, therefore, to consider both the degree of heat denaturation and granulation.

The toasted product is generally preferred in ground meats, cookies/crackers, and cereal applications, as well as in milk replacers and fermentation media. The more dispersible types are used in bakery products when added directly to the dough (e.g., bread, cakes, doughnuts, pancakes, etc.). Soy flour's main disadvantage has been its taste and mouthfeel.

Soy grits are identical in composition to soy flours; the only difference being its particle size. As with soy flour, toasted grits are preferred for ground meat applications and are also used to enhance the nutritional and textural quality of cookies, crackers, and specialty breads. Another big market is for pet foods and vitamin carriers.

Lecithinated and refatted soy flours are mainly used in bakery applications such as doughnuts, and sweet goods. (Lecithin content varies from 0.5 to 15 %. The soluble versions are also used extensively in pancake mixes and cakes/cake mixes.

Soy Protein Concentrates (untextured) - Since the neutralized acid leach and steam injection/jet cooking processes can result in a product that has a higher dispersibility, concentrates of these types will have more desirable functional properties in emulsion-type applications. These dispersible functional concentrates have many of the properties exhibited by neutralized isolates, described in more detail later on.

Concentrates may vary as to color, flavor, particle size, water and fat absorption. All of the soy protein concentrates, regardless of the process used, do have fat and water-holding properties (partially due to their polysaccharide content), and modify viscosity and textural characteristics of the food system. The alcohol denatured concentrates exhibit good nutritional value and are used in many applications requiring protein fortification. They may also be texturized. All concentrates have much improved flavor characteristics as compared to commercially available soy flours.

In general, the greatest potential areas are where casein and nonfat dry milk are used, such as emulsion-type meat products, bakery products, nutritional powder drinks and soup bases. Baby foods, cereals, dry food mixes, milk replacers, pet foods and snacks are just a few more examples where powdered soy protein concentrates may be used.

Soy Protein Isolates - Several soy protein isolates have been developed for providing different functional or physical properties to meet the requirements of various food Systems.

The solubility of isolates ranges from 25 NSI (Nitrogen Solubility Index) to 95 NSI. While solubility is very important, it is difficult to predict the performance of a protein in an application based on solubility alone. Other criteria, such as emulsifying capacity, gelling, fat and water absorption, viscosity, etc., should also be considered.

The emulsion capacity of isolates can differ by a factor of nearly four. Emulsion capacity or the ability of a protein to emulsify fat is the most important functional parameter in many food products. Isolates can emulsify from 10 to about 35 ml of oil per 100 mg of protein. On the other hand, where maximum emulsifying capacity of the proteins is not needed, and where thermal thickening and gelation occurs, initial solubility may not be too critical because stable emulsions can be formed with adequate energy input.

The film-forming properties of soy protein isolates are useful in certain meat products. Applying heat and pressure causes protein films to fuse together to form a firm, continuous, textured mass that can be sliced and used as meat substitutes.

Soy protein isolates vary in their ability to form gels. Some are designed to form gels while others will not form gels at 14 % solids content, with salt content also affecting the gel strength.

The viscosity properties (thixotropic) illustrate again that all isolates do not have similar properties. Some isolates will have the same viscosity at 18 % solids as other isolates have at only 10 % solids concentration. The application of heat and shear to the protein solutions can also alter their viscosity.

Water and fat absorption properties are also utilized in meat and baking applications. Isolates have water absorption values from about 1 50 to 400 %.

Neutralized isolates are usually highly dispersible and will gel under appropriate aqueous conditions. They possess both emulsifying and emulsion stabilizing properties, and are excellent binders of fat and water, and are good adhesive agents as well. For this reason, they are used in processed meat products, both coarse and fine emulsions (e.g., patties, loaves and sausages). Some of the general purpose isolates (non dispersible) have good nutritional properties and vary mainly in their gelling and viscosity characteristics.

Similar examples could also be cited for functional " concentrates ; for the sake of brevity, however, illustration of these general properties has been limited to isolates.

Isolates and concentrates can also be structured to have a fibrous appearance. These products are designed mainly for poultry and meat protein replacement. The fiber-like structure, for example, adds texture and mouthfeel to poultry rolls.

Soy Albumens - In contrast to the unhydrolyzed proteins, the soy albumens (partially hydrolyzed proteins) are soluble in water in both the acid and alkaline ranges, soluble in hot syrup, and can be pasteurized without coagulation. They can be used in many products as aerating agents, but in some applications are used in combination with egg albumen or with whole eggs to improve the whipping rate, and stability of the whips. These modified proteins have found a limited but important place in the food industry for the preparation of confections and desserts.

Textured/Structured Soy Protein Products - They are many types of textured proteins from different processes and starting materials. Textured protein products are being prepared commercially by thermoplastic extrusion of flours, grits and protein concentrates under heat and pressure to form chips, chunks, flakes, and a variety of other shapes. These products can be flavored to resemble or extend meats, such as hamburger, stew meats, and beef chili, and are widely used as meat extenders.

Their structure and texture can be modified by varying extrusion parameters and by the addition of salts to the mix before extrusion. They also absorb water, and to some extent fat, so they can be regarded as having physical functions, in addition to their main role as extenders. They may be incorporated in a dry, partially hydrated or fully hydrated form. The manner of incorporation is based primarily on specific food formulation, processing equipment and the type of ingredient Used. Obviously, textured flours require less water for hydration than concentrates. The minced or flaked form is designed for rapid hydration.

These ingredients are also used in retorted products to absorb juices liberated during canning, resulting in a less sloppy or firmer final product. Examples of this type of applications are beef patties, sausages, chili, sloppy joes, pizza toppings, taco fillings, meatloaf mixes, frozen dinners, meatballs, Salisbury steak, tamales, packaged dinners and soups, canned minced hams, meat pie fillings, hot snacks, vegetarian foods, and pet foods. Hydrated textured soy proteins should be handled like meat or any other perishable food when preparing them for meat product.

Structured concentrates are extruded products made to have a fibrous or laminar rather than a spongy structure. In general, structured concentrates also have higher water absorption and hydration rates (2-5 minutes vs. 30-60 minutes) than those of textured flours and granular concentrates of ten years ago, and their structure and texture stands up to retorting much better.

Flavor and Texture

Proteins affect the sensory properties, i.e., appearance, color, flavor, taste and texture of foods. These are key attributes that determine consumer acceptance. The flavor of soy proteins and their interaction with both desirable and undesirable flavors is extremely critical and determines the acceptability of foods containing soy preparations, and thus the application of soy proteins.

Much progress has been made in reducing flavor, especially with refined products such as concentrates and isolates but residual flavors always remain, although they are often diluted and masked when the proteins are incorporated into foods at low level. Flavor is a particular problem in bland foods, such as dairy products.

Soy proteins also suffer from the absence of desired flavors, such as those of meats. When used as meat extenders, textured soy products dilute the natural flavors of meat. Flavors are frequently added, but they are often released too rapidly.

It could be misleading to extrapolate from the flavor of the product per se, or its flavor in a given food System to its probable flavor acceptability in a different food system. Most researchers who are experienced in food product development are aware of the phenomenon of flavor compatibility as a function of the total food system. No doubt, more research is needed to find practical methods for further reducing flavor levels in soy proteins, for developing desired flavor compounds in finished foods, and for adjusting conditions in a given food system so that flavor compatibility is optimized among all factors contributing to organoleptic sensation.

USES IN FOOD SYSTEMS

Since the general application possibilities for soy protein products have already been mentioned under" FUNCTIONALITY ", only principal use areas that need special highlighting are discussed under this Section.

Meat Food Products

Because of changing attitudes of consumers, processors, and regulatory agencies, soy protein products are being used at an increasing rate in various processed meat systems. The largest area of current domestic food utilization is in emulsified meats (frankfurters) and coarse-ground meats (ground beef patties).

Emulsified Meats - For many manufacturers, it is important to use additional emulsifiers/binders as insurance against product failure. The non meat proteins must perform the same functions as the salt-soluble meat proteins. These functions include emulsification, emulsion stabilization, gelation, and fat and water binding, among others. Depending on the protein ingredient used and the meat product, levels of usage range from 1 to 4 %.

Many emulsified meat formulations containing soy protein products have excellent eye appeal, good texture, no off-flavors, and result in substantial savings (reduced cooking losses and greater yields) while, at the same time, maintaining good nutritional quality.

Soy protein isolates and " functional " (dispersible) concentrates are the most effective soy ingredients used in emulsion-type meats.

Coarsely-Chopped Meats - In coarsely-chopped meats (e.g., meat patties, meat balls, chili, Salisbury steaks, pizza topping, and meat sauces) textured soy protein concentrates and soy flours are the ingredients of choice. Usual hydration levels are ca. 2.5 to 3.5 : 1 but higher levels are possible. A good guide in hydrating soy products is to achieve a protein level in the hydrated form of ca. 18 %. If too little water is used to hydrate the product, the extended meat product will be dry.

The flaked form assures rapid hydration that makes the ingredient well suited in high volume applications. Its meat-like appearance and mouthfeel remain intact throughout strenuous retort and freeze-thaw conditions while contributing to overall stability of the fat tie-up system.

In supplementing ground meat in a pattie-type product, extensions can be made up to about 20 % without flavor adjustment. Above this level, it is necessary to use additional seasonings to offset the dilution effect of the bland ingredient on the taste of the meat.

The primary function of the protein is to improve the dimensional stability of the patties, preserve the structural integrity of the ground meat pieces during thermo-processing, and help to retain meat juices (i.e., decrease cooking losses). When properly used, the patties or other types of ground-meat products will be tastier, will have a higher protein content and lower fat, and thus are better balanced nutritionally.

Textured vegetable proteins fortified with vitamins and minerals, when prepared and served in combination with meat, poultry or fish, may be used as meat alternates to meet part of the minimum requirement of the USDA School Lunch program. Formulated pizzas for children are also in general usage in the schools. Textured vegetable protein often is used as one of the protein ingredients in pizza toppings, along with the meat and cheese.

There is also a large market in military and other types of institutional feeding, in addition to the School Lunch Program. In the United States the military purchases more than one-half of its beef in ground form. Soy-extended beef is used to achieve significant cost savings. The extender approved is textured or granulated soy protein concentrate which, in a hydrated form, can be added at about the 20 % level (5 % on a dry basis).

Varying amounts of texturized soy protein products are used also in combination with powdered functional concentrates or isolates in patties and other types of ground meat products such as meat balls, pizza toppings, taco fillings, sloppy joe mixes, etc. The tremendous cooking yield advantages obtained by these combinations have greatly enhanced their utilization in all types precooked items and entrees.

The variety of formulations in today's portion-controlled ground meat products is limited only by the food technologist's creativity and ability to machine the meat mix on high-speed forming equipment. Although more and more textured soy proteins are used in retail stores, the institutional trade is still the mainstay of current sales. This is probably not due to perceived labeling problems on the part of the consumer, since there has been no large-scale effort to advertise the benefits of soy protein to an informed consumer market. Many previous attempts in retail marketing of soy proteins in processed meats failed, most likely, because of poor positioning, pricing or just plain misusing the ingredient (e.g., to cover up the poor quality meat in the formula) rather than because of the alleged unfavorable " image" of soy per se.

Canned Meats - Soy protein ingredients (mainly textured) are also used in retorted products to absorb juices liberated during canning, resulting in a less sloppy or firmer final product. Structured concentrates have an advantage over other forms in any retorted product because they can be used at fairly high levels and they maintain their textural integrity under retorting conditions.

The combination of a textured soy product and an isolate or a " functional " concentrate with an emulsifier (e.g. lecithin) provides superior functionality over a single ingredient by not only increasing the protein content but also by resulting in a pleasing uniform texture with no fat separation.

Whole Muscle Meals - It is possible to incorporate an isolate or a " functional " concentrate into large pieces of muscles (ham, roast beef, poultry, fish, etc.). A brine containing one of these products is injected or massaged into the muscle using conventional cured meat technology. Alternatively, the intact muscle pieces can he injected first with brine, and then the protein incorporated by massaging or tumbling. This process can be used to increase yield by 20 to 40 %, over the " green weight. Product quality attributes include normal appearance, improved firmness, and slicing characteristics as compared to conventional brined-cured hams, combined with less wee page under vacuum packaging.

Poultry Products - Poultry products are also consumed in two basic forms: whole muscle and comminuted.

Vegetable protein ingredients, including vital wheat gluten, " functional " soy concentrates and isolates are being used to bind meat cuts and trimmings to make pressed loaves and poultry rolls. Poultry breasts pumped with slurries of soy protein isolate, salt and flavors are also becoming popular.

Products such as boneless turkey and comminuted chicken loaves present to the poultry processor problems similar to those faced by the sausage maker. Field reports indicate that soy proteins are finding increasing use for this purpose.

Seafood Products - The use of soy protein in traditional seafood is best illustrated by the Japanese fish-based products. These are traditional comminuted gel-like products that have been consumed in Japan for centuries and are based on a minced fish flesh ingredient called surimi. Outside Japan, soy proteins are not being widely used in traditional seafoods. Opportunities exist today, however, and soy proteins can and will impact on the seafood market.

In the last few years textured soy protein ingredients have been advocated as seafood extenders. In one use, hydrated textured material is mixed with ground or minced flesh and a matrix-forming material. The mix is extruded or molded into various shapes, usually in the form of sticks or shapes characteristic of shrimp or fish. These products are then battered, breaded, fried, and frozen. In another use, hydrated textured proteins may be used in extending items such as imitation crab and shrimp, tuna salad, fish patties, etc.

The water absorption and retention properties of certain soy proteins could also be used to bind moisture in fish blocks, bind fish pieces in minced fish blocks, and to pick up some of the fish moisture lost during processing.

Analogs - Complete meat analog products such as bacon crumbles, breakfast sausage, etc., have been in the retail stores for several years. Flavored soy proteins for use as salad toppings and replacement for nuts and vegetable crops (bell peppers) are also being developed for the retail and institutional markets.

Analogs which are produced to resemble conventional foods in appearance, color, flavor, and texture, represent the ultimate adaption of soy proteins. All-vegetable protein analogs resembling ham, turkey and sliced beef are being marketed in vegetarian-type foods. While these products, associated with religious groups and health fads, have a limited market, with current interest in health on a broader front, there may be a new opportunity for formulating meals with lower or no animal fat in order to develop low cholesterol entrees.

Well-known soy analogs for the general population include breakfast meats, foods for backpacking, whipped cream, and imitation cheeses.

Pet Foods - One should not overlook another closely-related industry in an affluent society, namely, the pet food industry. The future will very likely see a major portion of this market being supplied by textured vegetable protein products, made primarily from soy protein.

Dairy-Type Products

Isolates are the most acceptable products for dairy applications because of their fine particle size and dispersibility. The functional properties of emulsification, emulsion stability, color, and flavor/ odor are critical factors in dairy applications.

Although isolated proteins offer much potential in the manufacture of dairy-type products, these products are not yet produced in the U.S. in significant volumes. A few, such as dry and liquid coffee whiteners, liquid whipped toppings, pre-whipped toppings, and toppings of other emulsified food items to replace sodium caseinate enjoy distribution in the U.S. There is considerable development effort being devoted to a broad variety of other dairy-type foods: imitation milks, convenience beverage powders, frozen desserts, sour cream, sour cream dips, and related cheese-like products.

With the development of soluble concentrates and isolates, the manufacture of higher quality soy-based baby foods became possible. These products have improved color, flavor, odor, and do not contain the flatus producing carbohydrates found in soy flours. Soy protein isolates supply almost all of the protein in the liquid formulas. Approximately 10 % of the formula-fed infants are being fed formulas containing soy protein. Soy protein formulas are recommended for those infants, and others, who are allergic to milk protein and those who have lactose intolerance or lactose deficiency.

In addition to the milk-free or soy-based infant formulas, special formulas utilizing soy protein products are designed and manufactured for older infants, geriatric, hospital and post-operative feeding. Soy problem seems also to have an assured role in dairy product analogs made for people who have special health or religious diet requirements.

Full-fat and defatted soy flours have been used successfully as major ingredients in low-cost replacements for milk solids in beverages for human consumption in developing countries. The worldwide market for soy milk products has been growing at a fast pace.

Soy protein concentrates are preferred in milk replacers for baby animals such as calves, lambs and pigs because of their low soluble carbohydrate content (i.e. less gastro-intestinal disturbance problems) and lower immunogenecity. The proteins are used to form fat emulsions as a method for incorporating fat into the formulation and to provide protein for nutrition.

Soy protein ingredients are now being used in emulsion-type cheeses to replace as much as 50 % of sodium caseinate in some products. Fermented soy cheese-like products have been tried but there is still a lot of research needed before the textural/rheological properties of dairy cheese can be reproduced in a satisfactory manner. One of the properties that is lacking in these products, but is important in pizza, is the " melt-down " upon baking that is characteristic of mozzarella cheese.

Soy and milk protein blends (combined to offer a protein content similar to that of milk) are sold as ingredients in bakery products, sauces, meat products and various fabricated foods, as complete or partial replacement of nonfat dry milk.

Present U.S. Federal and State dairy laws greatly restrict competition by modified or imitation dairy products, and retard new developments in this area. Sooner or later, however, new soy products, having better flavor arid tailored-made functional properties, will play an increasingly greater role in dairy-type products.

Bakery Products - Cereals - Pasta

In bakery products, cereals and pasta, soy protein ingredients are being used for a variety of economical, functional, as well as, nutritional reasons.

Because of price and the compatibility of particulate vegetable fiber with most bakery products, defatted soy flour is the most widely used soy ingredient in these applications as a partial replacement for nonfat dry milk. The greatest usage for soy proteins in bakery foods is in combination with other ingredients, such as sweet dairy whey.

Milk replacer blends are available at protein levels ranging from 20 % to as high as 40 %. The nature of the blend is dictated by the functional and/or nutritional requirements for the product in question. Defatted soy flour is the primary soy product used in these blends, but concentrates and isolates are also used, as partial or complete replacements for non fat dry milk. These blends are used partly for reasons of economy, and partly because some bakers want to retain some dairy product in their bread formulas as an image builder.

Bread and Roll - When defatted soy flour is used at the rate of 1-3 % (flour basis) in bread and buns, it increases absorption, improves crumb body and resiliency, enhances crust color, and improves toasting characteristics. The keeping of freshness in bread is probable due to the retention of free moisture by the soy protein that is preserved even during the baking cycle.

As mentioned before, reduced crumb color can be produced with high-enzyme soy flours that have high lipoxidase activity. Darker crust color can also be obtained with soy flours having low lipoxidase activity because of the high lysine content of the soy ingredient, i.e., the free amino group in lysine reacts with reducing sugars to form the Maillard reaction.

Heavily toasted grits with a PDI of 20-30 are used in wholegrain, multigrain, and natural grain breads to add color and a nutty, toasted flavor.

Nutritional studies indicate that the protein quality of commercial white bread containing 3 % soy flour is equal or slightly superior to bread containing 3 % nonfat dry milk.

Specialty Breads - The protein content of ordinary white bred is 8 to 9 %. Specialty breads can be made with 13 to 14 % protein by incorporating soy flour, concentrate or isolate in the formula, along with vital wheat gluten and, if necessary, a lipid emulsifier (e.g., sodium stearyl-2-lactylate or ethoxylated monoglycerides). Without surfactants, incorporation of high levels of soy flour depresses loaf volume and gives poor crumb characteristics.

In non-standardized breads with higher levels of soy protein, there are dramatic changes in the nutritive value of bread. When 12 % soy flour is used, the P.E.R. increases from 0.7 to 1.95. In addition to the improvement in protein quality, the protein content is also increased by more than 50 % at this level of supplementation. Soy-fortified wheat flour has been used world-wide in mass feeding and school lunch programs.

Cakes and Cake Mixes - Soy protein products, including soy isolate-whey blends, have been evaluated in pound cakes, devil's food cakes, yellow layer cakes, and sponge cakes, in which 50, 75, 100 percent of the non-fat dry milk can be replaced without impairing quality.

Defatted and full-fat soy flours and grits are added to cake, bread, pancake, waffle, and many other baking mixes at levels of 2-1 5 %. In many of these mixes other types of soy proteins may also be added, e.g., isolates or concentrates, depending on individual formulation requirements. Soy protein products in these mixes help with the emulsification of fats and other ingredients. The resulting doughs are more uniform, smoother and pliable, as well as less sticky. The finished baked products will have improved crust color, grain, texture, symmetry, and longer freshness.

Lecithinated soy products are often used (3-5 %) in heavier cakes, such as sponge and pound cakes, because of the increased richness and emulsification functions they provide. In addition, the high-fat or lecithinated soy flour may permit reduction in eggs and shortening.

Doughnuts - Doughnuts containing soy protein absorb less fat during frying, because fat cannot penetrate into the interior. This is probably due to the heat denaturation of the protein containing surface area that acts as a harrier. This results not only in a better quality doughnut, but also in a more economical formula, by lowering frying oil costs. Used in the range of 3-3.5 % of the formula, soy flour gives doughnuts a good crust color, improved shape, higher moisture absorption with the resultant improvement in shelf life - and a texture with shortness or tenderness. Lecithinated soy flour is recommended for doughnut formulas with minimal egg yolk levels.

Breakfast Cereals - New emphasis on nutrition in breakfast cereals has meant more use of soy proteins to increase protein quality and quantity. Soy proteins are also used in hot cereal mixes, and as components of granola bars and compounded breakfast bars.

Pasta Products - Pasta products of all types, such as macaroni, spaghetti, etc. are being fortified with soy protein to increase nutritional value. Foods of these types have accepted by the U.S. military, government feeding programs, and school lunches. Defatted of full-fat soy flours are most commonly used. These pasta products contain soy flour at 15 % level on a dry basis, with a 15-17 % protein content. If desired, vitamin enrichment can be included.

Acceptable commercial-grade pasta products (e.g., spaghetti) can be prepared from durum semolina fortified with soy protein products, especially isolates. Soy products increase the absorption of spaghetti dough and promote firmness - a special advantage for pasta subjected to long cooking periods. Soy protein isolate usually produces the lightest color.

Miscellaneous Baking Applications (sweet rolls/cookies/pastry/crackers/snacks, pancakes, etc.)

The functional properties of soy proteins are the same in these applications as those described for the previously mentioned bakery products. The incorporation of a white soy flour, or a mildly lecithinated soy flour, in a pancake formulation at the 3 % level will result in a golden brown product with improved light and fluffy texture, with a reduced tendency to stick to the griddle.

In sweet goods, 2-4 % defatted soy flour improves water-holding capacity, sheeting characteristics, and finished product quality. In hard (snap) cookies, the use of 2-5 % defatted soy flour improves machining and produces cookies with a crisp bite. “Short “ pastry items such as pie crusts, fried pie crusts, and puff pastry can be machined more easily and will retain freshness longer when lecithinated soy flour is used at the 2-4 % level.

Miscellaneous Foods

Miscellaneous food applications include brew flakes (soy flakes/grits) ; soups, gravies and sauces confections, imitation nut meats ; and non-fermented Oriental soybean foods (soy milk, tofu, etc.). Canned soups, sauces, and gravies often utilize soy proteins to prevent separation of ingredients and to impart thickening essential to the identity of these products.

Other products concepts entering the retail market are those in the dry grocery products category. These consist of a pouch pack or boxed instant dinner concept, using soy proteins as functional ingredient.

Because the Orient is short in meat and dairy products, the food uses of the soybean make an important contribution to the protein and fat requirements of the peoples of Asia. In addition, these products have been used over the centuries to good advantage in many food preparations to give foods a desirable meaty flavor. Tofu is the most important example in this category and is also becoming more popular in Western countries. The traditional tofu is a highly hydrated, gelatinous product, containing about 88 % water, and is sometimes said to resemble cottage cheese. With modern manufacturing facilities other forms are now also available (e.g., dry tofu).

The confectionery field uses soy flour in various types of confections. Caramels and toffee-type products handle better with the inclusion of soy flour, and there is less stickiness on a high speed wrapping machine. In fudges, soy flour will slow the rate of dehydration and thereby aid in preventing the crystallization of the sugar.

Partially hydrolyzed soy proteins (albumens) are used to make nougats, creams, kisses, fudge, and similar types of candy, as well as meringue powders, icings, and other confections. Aeration is aided in these products by using hydrolyzed soy protein.

Because of the technology built into a complete line of soy-based textured ingredients, these can be used in an impressive array of foods - including frozen foods, salad dressings, pizza dressings, where the ingredients retain their shape, and add texture and flavor.

CONSUMPTION TRENDS

The industry producing edible soy protein products for human consumption has grown enormously since the late 50's, and its products are now available for large volume use. Current known yearly world production is estimated to be approximately 1,500 metric tons (3,300 million lbs) of soy flour, 90,000 metric tons (200 millions lbs) of soy protein concentrate, and 70,000 metric tons (170 million lbs) of soy protein isolate, which amounts to about 3.7 billion pounds of edible protein for human consumption per year. (Since soy flour is used in many developing countries where statistical records are incomplete, the figure for this ingredient could be higher than given here.)

Soy proteins appear to be the only large volume, commercial protein ingredients that will be used in the foreseeable future for both nutritional and functional purposes as replacements for traditional animal proteins. Other plant proteins are still in the potential category and show no signs of becoming a serious commercial reality in the near future. Some do enjoy a limited market, such as peanuts and wheat gluten, the latter as a functional ingredient in baked goods, and meat analogs.

A factor that has a direct effect on the price of protein ingredients is the available supply. This is an important consideration in the selection of ingredients by the food manufacturer. Vegetable proteins such as those of the soybean and wheat gluten are in a better position from the standpoint of availability than some of the animal proteins because of the large potential supply of starting materials, i.e., soybeans and wheat. Only about 2-3 % of the total U.S. soybean crop is used domestically as a direct source of protein (as opposed to the indirect use as in animal feed). Potentially, conversion of defatted soybean flakes to edible grade protein products could likely increase several fold without serious effects on the availability of defatted soybean meal for feeds.

With the demand for meat products declining in the U.S., and consumer interest in "healthy" foods increasing, new opportunities exist for the use of soy proteins in formulating low calorie, low-cholesterol and high-density protein items.

On the other side of the spectrum, there is a tremendous food shortage in most part of the world, both in terms of calories and protein, where protein fortification would fill a real need. The solution for this problem is economics and politics, with the nutritionist and food scientist playing only the role of an advisor.

The European market is using the whole spectrum of soy protein ingredients in the same way as is the case in the U.S. Notable exceptions are: more emphasis is being placed on emulsified processed meats versus ground meats (e.g. patties), and less defatted soy flour is used in bakery products. On the other hand, full-fat soy flour is manufactured and used in baked goods, especially in the U.K.

Isolates, concentrates, and textured soy products, although originally developed in the U.S., are now manufactured and/or consumed in Japan, China, India, Southeast Asia, Latin America (especially Brazil), Israel and Europe.

FUTURE CONSIDERATIONS

Reasonable projections indicate that the area of diet and health will continue to increase in importance in the form of calorie-controlled and tailored nutritional foods. Soy protein will have an excellent opportunity to get the focus of attention it truly deserves as a highly nutritious and economical food ingredient.

Food service is served well by the reformulation technology permitted by the use of soy proteins. Other food service benefits when using soy protein include better product uniformity and reduced cooking loss. There is no question that in this new era of "restructured" food technology soy protein products will play a key role because of their functional and texture-forming capabilities.

There will also be changes in product formulation, primarily in the traditionally conservative dairy and meat industries. These industries are now ready to experiment with new product concepts. Old ideas will change as new foods will be dictated by ingredient availability, implementation of modern process technology and distribution systems, marketing requirement and nutritional guidelines.

On the long run, as farmland become more expensive to work, and as feed costs rise, beef, pork and poultry products will become more expensive. Food processors will seek new sources of low cost, efficient proteins, such as the soybean or perhaps food from the sea.

The Soy Protein Market Potential Survey (Project 2002 - " Planning the Future of Soybeans", ASA Study 1982) projected a market of 1.9 billion pounds (50 % flour equivalent) for U.S. produced edible soy proteins for the next two decades. (This is nearly a three-fold increase from 1982.) In this study, the fastest growing segment was isolate 7 %**,** versus 4.5 %, for soy flour, and 5.4 % for all products combined (compounded annual rate). More recently, however, the demand for soy protein concentrates appear to have growing at the fastest rate.

The pet food and specialty feed markets have been identified as the single largest markets. Other fast growing areas were : soy milk, imitation cheeses, ground meat blends and extenders, and commercial bakery and confectionary ingredients.

SUMMARY

While soy proteins have largely been considered as economical substitutes for more expensive protein ingredients, they should be viewed as vital functional components that will enable the food technologist to fabricate new foods. Perhaps a new approach will emerge one day when soy foods and ingredients are marketed in their own right rather than just as imitations of other existing products.

In the meantime, soy protein products will continue to play an important role in providing the nutritious foods customers demand, and will be gaining in acceptance as useful and economical ingredients in the manufacture of conventional foods, and in the design of new foods.