Soy Products for the Meat Industry

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In comminuted meat products, the processor combines lean meat, fat, and seasonings to create nutritious items that have appeal to consumers at competitive prices. Variety in these products is achieved through the use of various meat cuts, by altering processing conditions, and through the use of seasonings and additives. Soy products as additives can contribute nutrition, flavor, and valuable functional properties to these meat preparations. When used as emulsifiers, binders, moisture retainers, and stabilizers, soy proteins can alter or improve the appearance, taste, and texture of the finished product. Soy proteins can also be used to extend or simulate meats. On the basis of protein content, soy proteins are the lowest cost functional proteins commercially available.

Soy products used by the meat industry contribute stability, nutrition, flavor, or economic advantages to various meat preparations. Although soy products may be used as inexpensive extenders, greatest advantage can be gained from their use if they are considered as functional ingredients.

Soy products obtained from soybeans by present day processing methods yield three important components: protein, oil, and lecithin. Of the three, only soy proteins are used to any extent by the meat industry.

Soy proteins may be modified into products that have utility alone or in combination with other materials. These modified preparations include textured proteins as well as those hydrolyzed for use as flavoring ingredients.

In this review, various soy protein products, their preparation and use by the meat industry will be discussed.

BASIC SOY PROTEIN PRODUCTS

Preparation. The basic soy protein preparations are obtained from hexane-extracted flakes that have a protein content of at least 50%. These defatted flakes are prepared from soybeans that are cracked, dehulled, flaked, and extracted.

Depending upon the method used to remove the solvent and upon the amount of subsequent moist heat applied, defatted flakes are obtained that range from a white flake to a toasted flake. This heat treatment has an influence on the water-dispersible protein content of the flake.

The white defatted flake exhibits lipoxidase, urease, and antitrypsin activities. Flavorwise, the white flake has a bitter, beany taste. The toasted product is darker in color and the enzyme and antitrypsin activities are destroyed (Liener, 1958). Its flavor is also improved to the point where it takes on a sweet nut-like taste (Rackis *et al.*, 1966). The intermediate or cooked product has properties between the two just mentioned.

Soy Flour and Soy Grits. Since soy flour and soy grit products are obtained by grinding defatted flakes, the protein content and other characteristics described for these flakes are imparted to the ground products. Soy grits are obtained by grinding flakes to particle sizes larger than 100 mesh. Soy flours are 100-mesh or finer products.

Soy Protein Concentrate. Soy protein concentrate (SPC) is produced from defatted soybean flakes by processes in which the protein is immobilized and the soluble sugars and mineral matter are removed, resulting in a preparation having a protein content of 70% on a dry basis (Meyer, 1966).

Currently there are three methods by which soy protein concentrates are made. These methods differ as to the means used to immobilize the protein: heat, isoelectric, and alcohol washed. All three methods are used commercially.

Isolated Soy Protein. Edible isolated soy protein (ISP) is produced by extracting a white flake with water or mild alkali (Meyer, 1966). The protein-containing liquor is separated from the flake residue and the protein in the liquor is precipitated with food-grade acid. The resulting curd is washed and spray dried in the isoelectric form, or the curd is neutralized previous to spray drying to produce a water-dispersible sodium proteinate. In both cases the protein content is greater than 90% on a dry basis. The sodium proteinate is the form used most widely by the meat industry.

Meat Applications. Fat is an important constituent in meat. It serves two purposes in that it improves texture and adds flavor. Without fat, meat tends to be tough and lacks the richness of flavor expected in meats.

The meat processor attempts to duplicate nature in this respect when he combines lean meat with fat. This is accomplished more efficiently if the meat ingredients are comminuted. Communition of meats is usually achieved by chopping, flaking, grinding, or similar processes. To achieve variety in comminuted meat products, the processor uses the following variables: meat selection, both cut and species; degree of communition; amount and types of additives and seasonings; processing conditions; and finally, size and shape of the finished item.

The most popular comminuted meat items in the U.S. are the sausage products which include the frankfurter and bologna. The Consumer and Marketing Service (C&MS) reported that 1,051,978,000 lb of frankfurters were processed during the year 1968 (USDA, 1968). DeGraff (1969) estimates that total frankfurter production for this same year, including those not under federal inspection, was about 1,500,000,000 lb.

Other popular comminuted meats are hamburgers, patties, and luncheon meats.

In the U.S. diet, meat is the chief item of practically every meal. Since meat is such an important course in our diet, meat processing is very competitive.

Although the processor is in the business of selling a protein, he must include fat in his product for both economic and organoleptic reasons. With a relative protein shortage and a fat surplus in today's market, it is necessary to use protein to carry the fat. The U.S population is particularly conscious of saturated fats. This makes it especially difficult for the processor to supply tasty products on a competitive basis.

Soy proteins are a natural adjunct in processed meats for a

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number of reasons. First, these soy protein products are high in nutritious protein that will complement the meat protein. Second, many of the protein products have emulsification and binding properties. Third, the soy proteins have the ability to hold in the meat juices, especially on cooking (USDA, 1968). And fourth, their costs are quite low. On the basis of protein, soy protein products are the lowest cost protein products available.

Sausage-Type Products. Soy flour has been used in additive type sausage and nonspecific loaves for a number of years. Its use is predicated on the fact that it is inexpensive. The cost per lb is about 7¢, or about 12–14¢ per lb of protein. Soy flour has the advantage of holding the meat juices. Its disadvantage is that of taste and physical feel in the mouth. In addition to regulatory restrictions, this drawback limits its use in meat applications.

Soy grits are also used in sausage, but to a lesser extent.

Although the cost of soy protein concentrate is more than double that of soy flour (18½–28¢ per lb), it is rapidly replacing the soy flour used in these emulsion products because of its blander flavor.

In most meat applications, the three different types of SPC all function in a similar manner (Central Soya, 1965). Other than mesh size considerations, there are differences that should be noted. The heat denatured preparation will have a dark color and a low water-dispersible protein content, lower than 10%. The alcohol-wash preparation will have a light color and a lower water-dispersible protein content, about 10%. The isoelectric-wash product, which has been neutralized, will have a light color and a water-dispersible protein content that is higher than the other two. This usually is in the range from 25–50%.

Although isolated soy protein has application in sausage products, it is being used to a greater extent in nonspecific loaf type products where there is no restriction on the amount of water used. Federal standards permit four times the meat protein content plus 10% water in cooked sausage products. To obtain the greatest cost advantage from an extender type of product, the amount of moisture and meat juices it will hold must be considered.

Circle *et al.* (1964) reported that 8 to 14% aqueous dispersions of ISP will gel within 10 to 13 min at temperatures of 70° to 100° C. The gels are disrupted if overheated at 125° C. Above 16–17% ISP concentration, the gels are less susceptible to this heat.

ISP also has the properties of emulsification and emulsion stabilization (Rock *et al.*, 1966). It is believed that these properties give it an advantage over nonfunctional meat extenders.

In making sausage products, the processor depends upon the binding properties of heat-coagulable proteins, myosin and actimyosin, contained in red skeletal meat (Rock *et al.*, 1966). Because these meats are expensive, they are often used sparingly, resulting in marginal formulations. If this is complicated by mishandling of the meats, natural variations in meats and processing variations, the emulsion structure can be greatly weakened. This leads to emulsion breakdown during the cooking cycle. Since the food value of these items is good, they are reworked into a new sausage emulsion. This increases the cost not only because of the labor involved, but a new formula adjustment must be made to handle the added stress. Isolated soy proteins are often used as insurance ingredients to keep such failures to a minimum (Rock *et al.*, 1966).

Federal regulations permit soy flour, soy grits, and SPC in sausages up to a level of 3½% based on the finished weight of the product. ISP is permitted only at a level of 2%.

When used in sausage products having a standard of identity, the soy ingredient must be shown on the label in a prominent manner contiguous to the name of the meat product. It must also be listed in the ingredient declaration in the order of decreasing amounts.

Other Processed Meat Applications. Soy flour, soy grits, and soy protein concentrate are all used in portion controlled meat patties. The fine ground soy products are used to a lesser extent than the coarse ground materials. In this application an upper level of about 6 lb to 100 lb of ground meat is the limit of acceptability for the flour and grit products. SPC can be used at a higher level because of its blander flavor. In using these products it is necessary to add water from two to three times the weight of the soy protein being used.

When used properly, these patties will be tastier and have a lower fat content. In addition, the yield of patties per 100 lb of meat will be increased, which will result in a lower cost per pattie. Because of its affinity for water, the soy protein will retard cooking shrink. Field experience has indicated that a 30% fat pattie will shrink about 25%, whereas the same pattie extended with soy protein and water only shrinks about 10% less, *i.e.*, about 22.5%.

As of this time, there is no restriction in additive type patties other than "sufficient for purpose."

In preparing chili con carne, much of the fat renders out of the meat. This fat is retained in the preparation through the addition of various types of meal products, such as corn and/or soy. In the latter case, the addition results in a higher protein content than that achieved by the corn meal. Both products are equally effective.

It should be pointed out that an additional benefit is achieved when a large particle soy grit or SPC product is used in this application in that the particles add to the richness of the texture, more grainy in consistency. Flour tends to thicken the gravy portion.

In the chili con carne application, soy flour, soy grits, and SPC are permitted up to a level of 8% in the preparation in federally inspected plants.

As with meat patties, soy flour, soy grits, and SPC products are permitted in meatballs (in spaghetti) and in salisbury steak up to a level of 12%.

As with imitation sausage and nonspecific loaves, the government permits both soy flours and soy grits in soups, stews, scrapple, tamales, meat fries, pork and barbeque sauce, and beef with barbeque sauce "sufficient for purpose."

As part of the policing function, the Meat Inspection Laboratory (MIL) of C&MS must be able to determine the amount of additive used in the product. MIL uses the method published by Bennett (1948) to determine the amount of soy flour and cereal in meat items. This method is essentially an alcoholic-KOH digestive procedure to obtain hemicellulose, which is then solubilized in hydrochloric acid. After their separation they are reprecipitated by the addition of 95% alcohol, centrifuged, and measured volumetrically. Separate conversion factors are used for cereal starches, soy flour, and soy protein concentrate.

Before ISP can be used in federally inspected plants, it must be tagged with 0.1% titanium in the form of titanium dioxide. Thus, the quantitative analysis for ISP is based on a colorimetric determination for titanium. The unpublished method was presented and accepted by C&MS. In using this method, the sample is reduced to an ash which is dissolved in a solution of potassium and sulfuric acid. The titanium content is determined spectrophotometrically via the yellow titanium-peroxide complex.

HIGH PROTEIN–LOW FAT PRODUCTS

Firmness in a sausage product is dependent on the amount of lean meat in the formulation, whereas fat tends to soften the product and make it more tender. This tendering effect is also noted if excessive amounts of ISP are used. Hence, this is a limiting factor in its normal use. Advantage can be taken of this factor in the production of a high protein, low fat sausage product. In this case the combination of ISP and water (1 to 3 by wt) can be used in place of fat.

The Central Soya Research Laboratory (1965) was able to formulate an acceptable fish frankfurter that consisted of 19% protein and 3% fat. Meat items were also produced that had fat contents ranging from 6 to 15%. In a commercial demonstration a frankfurter was produced that analyzed as follows: moisture, 69.4%; fat, 6.6%; protein, 17.8%; ash, 3.0%.

When compared with a frankfurter having a fat content of 30%, not only is the amount of saturated fat greatly reduced but also the calorie content is significantly lower.

TEXTURED VEGETABLE PROTEIN

Soy proteins are playing an important role in the development of textured vegetable protein products. These products are quite versatile in that they can be used to simulate many food items such as various meat products, shredded coconut and dried fruit and nuts (Martin and LeClair, 1967). Texture is obtained by either fiber spinning or thermoplastic extrusion processes.

Spun Fibers. The basic process in preparing fibers by spinning was described in a patent by Boyer (1954). Further improvements are also described in some additional patents (Boyer, 1956; Boyer and Saewert, 1956; Giddey, 1960; Kuramoto *et al.*, 1965). An excellent description of these patents as well as other related ones has been reviewed by Noyes (1969).

Fibers are prepared by extruding an alkaline dispersion of soy protein through spinnerettes into a coagulating bath. The resulting fibers are then stretched to impart a toughness or chewiness to the product (Odell, 1966; Thulin and Kuramoto, 1967).

In the production of a simulated meat item, the fibers are combined with fat, coloring, flavoring, and heat-coagulable protein, they are formed or shaped, and then cooked. After fabrication the product may be sliced, ground, or dried. They may be consumed as is or processed further into frozen, canned, or dried products (Thulin and Kuramoto, 1967).

Fabrication may also include several different processes that are recombined to simulate specific products. As an example, simulated bacon slices are made by laying down fibers randomly together with the edible binder. Some layers are colored to simulate meat; others are colorless to represent fat. These are formed ino a multi-layered slab that is heat-set, then transversely cut into slices (*Food Eng.*, 1969).

Thulin and Kuramoto (1967) reported that a typical product with which they worked was composed of 40% protein fiber, 10% binder, 20% fat, and 30% flavors, colors, and supplemented nutrients. On a dry basis the meat analog analyzed as being 60% protein, 20% fat, 17% carbohydrate, and 3% ash. In a ready-to-eat state, most of these products contained 50 to 70% water.

The cost of the unflavored spun soy fibers in an acid-salt media is about 50¢ per lb (*Food Process.*, 1969). Thulin and Kuramoto (1967) point out that "Diced, boneless, cooked chicken meat, in natural proportions, is currently priced to manufacturers at $0.85 to $1.05 per lb." At first glance it would appear that these items are more expensive than the meats they are replacing. It should be remembered that these synthetic foods are cooked, boneless, and in a completely edible form. Hence, it would be more realistic to compare prices on this basis, which is in favor of the simulated products.

Thermoplastic Extrusion. The thermoplastic extrusion process is also being used by a number of companies to produce simulated meat. The cost of these materials is less than the spun fiber products because soy flours may be used instead of isolated soy protein.

The equipment used in making these products is similar to that for thermoplastic resin type products, *i.e.*, continuous extrusion cookers (Archer Daniels Midland, 1966). The technology in making meat analogs by this route is similar to that in making snack foods.

Depending upon the condition of the starting material and other factors, the extruded particles may be compacted or expanded. In most cases it's the expanded form that is of greatest interest.

In this process a mixture of soy flour, water, flavoring, and coloring is subjected to heat and pressure for a predetermined time. This mass is extruded into the atmosphere or at a reduced pressure to allow expansion (Archer Daniels Midland, 1966). Shape and size is determined by the size and shapes of the exit dies as well as to the frequency that the extruded material is cut from the dies by a revolving knife. At this point, the extruded material is still quite moist and further drying is necessary.

The unflavored dried product has a moisture content of 6 to 8%, protein 50 to 53%, fat 1.0%, fiber 3.0%, and ash 5 to 6% (Martin and LeClair, 1967; Archer Daniels Midland Bulletin 1126, 1967; H. B. Taylor Co., 1969). Martin and LeClair (1967) reported the densities of the textures of these products may range from 9 to 25 lb per cu ft.

Although these products will hold three times their weight in water, the rehydrated form usually is 30% solids (Archer Daniels Midland Bulletin 1126, 1967; Martin and LeClair, 1967).

In the preparation of the meat analogs, fat as well as other ingredients is added. Although the dry low fat product is capable of holding close to its own weight in fat, analogs will contain less, probably in the range from 6 to 30% (*Food Process.*, 1967; Martin and LeClair, 1967).

A number of analogs are being used as extenders in comminuted meat items, such as canned chili, spaghetti sauce with meat, meat loaves, salisbury steak items, and patties. Undoubtedly they have use in many more applications.

These textured products in the unflavored chunk or granular dry form vary from 12¢ to 40¢ per lb (*Food Process.*, 1969; H. B. Taylor Co., 1969). Since the dry form rehydrates with two parts of water, the cost of an as-served basis is in the range of 4¢ to 13¢ per lb (*Food Process.*, 1969). The colored or flavored products range in price from 33¢ to 80¢ per lb (Martin and LeClair, 1967).

The chief advantages in using the analogs in meat products are low cost, good storage stability, and appearance. Special products can be made for those concerned about diet for either religious or health reasons. In the latter instance, the amount and type of fat can be controlled.

The present day disadvantages of meat analogs appear to be only temporary ones. Duplications of color and flavor are the real laboratory stumbling blocks for making synthetic foods, as pointed out by Bauermann (1969). It has been noted that there is a tendency for the color to leach out of these products and for the products to become soft in water systems.

DRIED MEAT PREPARATIONS

The patent of Coleman and Creswick (1966) concerns a process used to prepare meats for dried soup mixes.

Since tenderness, color, and flavor in dried meat preparations are hard to control by ordinary means, the problem was corrected by tearing down the meat structure and rebuilding it. In the process, meat is mechanically reduced to fibers and then recombined with a premix consisting of isolated soy protein (sodium proteinate), egg white, fat, and salt. The combination is mixed with water to form a dough which is extruded through shaped openings of a meat grinder. The particles are heat coagulated and dried in a circulating oven until the moisture level reaches 2%.

The advantages obtained in using this method are: uniformity in size, shape, texture, and flavor. In addition, texture can be controlled through the proper combination of egg white and isolated soy protein addition. Dehydration is achieved economically and rehydration is both rapid and uniform. The shelf stability of the preparation is considered quite good.

It is interesting to speculate that this is a method whereby a simulated meat product can also be formulated from inexpensive meat items such as poultry. Thus, using poultry meat fibers as a base, proper flavoring and structuring can lead to simulated pork, beef, ham, bacon, and other meats.

HYDROLYZED VEGETABLE PROTEIN

The Orientals not only recognized the flavoring properties of hydrolyzed vegetable proteins but used these products to an advantage in many of their food preparations. Since most of their meals were meatless, they used these preparations to give their foods a meaty flavor.

Soy sauce or shoyu was obtained from a combination of soybeans and wheat through a fermentation process that took as long as 1 1/2 yr to complete (*Soybean Digest*, 1966). At the end of the fermentation the extract is heated and processed to produce a liquid product familiar to most of us.

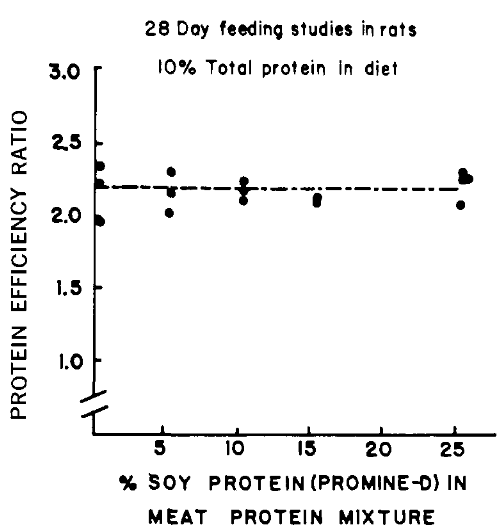

Figure 1. Nutritional value of meat protein–soy protein mixtures (Meyer, 1966). From: *Proc. Int. Conf. Soybean Prot. Foods* **(1966)**

Table I. Nutritional Value of Soy Protein Products

Rat Feeding Studies: 10% Protein Diet—28 Days

Product	Protein Efficiency Ratio (range)	Reference
Soy Flour (defatted)	2.16–2.48	Central Soya, 1963; Curtin, 1966
+1.0% *dl*-methionine	2.97	Longenecker *et al.*, 1964
Soy Protein Concentrate	2.02–2.48	Meyer, 1966
+1.5% *dl*-methionine	3.09–3.24	
Isolated Soy Protein	1.08–2.11	Meyer, 1966
+1.5% *dl*-methionine	2.11–2.45	

"In the United States, the major portion of protein hydrolyzates is prepared from soybean protein, wheat gluten, or milk protein by acid hydrolysis. However, a number of enzyme hydrolyzates are commercially available as flavoring agents. . . .

Acid hydrolyzates of vegetable protein require neutralization of the acid with sodium hydroxide which results in a salt content of 35 to 50% (solids basis) in the final hydrolyzate . . . Acid hydrolysis is usually carried out at temperatures exceeding 100° C under pressure" (Reed, 1966).

Sair (1968) described the preparation of a hydrolyzed vegetable protein achieved through the use of aqueous hydrochloric acid on edible proteins such as soy and wheat, until the α-amino nitrogen content is in the range from 35 to 55% of the total nitrogen content. This preparation is neutralized to a pH ranging from 4.5 to 7. It was pointed out that a partially hydrolyzed product yields a superior flavor.

The use of HVP in processed meat products is to enhance the meaty flavor of these products. Depending upon the preparation and type, HVP is used in concentrations usually ranging from 0.2 to 2% based on the final weight of the new product.

HVP is of particular value in those cases where bland products are used in conjunction with meats as extenders or binders. They are also used extensively in simulated meat products to contribute to the expected meat flavor (Kiratsous, 1969).

Hydrolyzed vegetable protein is cleared for use in federally inspected plants. The regulation simply states "in amounts sufficient for purpose."

NUTRITIONAL CONSIDERATIONS

Of concern to some processors in using soy protein products as additives in meat items is whether or not they detract from the nutrition of the meat. Table I shows the range of protein efficiency ratio (PER) reported for the three basic soy protein products.

Protein efficiency ratio is the relationship of the weight gain of a growing rat per unit of protein intake. A PER of 2 means that the average weight gain was 2 g for every g of protein consumed. Thus, the PER may be used to compare the nutritional value of various proteins on growing rats. The standard is casein which has a PER of 2.5.

All vegetable proteins, when compared with animal proteins, are lacking or limiting in one or more essential amino acids. Lysine is the limiting amino acid for wheat and corn. For soy proteins, methionine is the limiting amino acid.

Soy flours and soy protein concentrate are good nutritional sources of protein (Table I). When supplemented with methionine, they are considerably improved. Although ISP has a relatively low PER, when supplemented with methionine it, too, elicits an improved response in the rat.

Figure 1 shows the PER's observed in feeding studies in which rats are fed mixtures of meat protein and ISP. The meat protein was replaced from 0 to 25%. This figure shows that there is little if any change in observed PER's in the replacement up to 25%.

In the case of meat analogs prepared by extruding soy flour, the PER's are similar to that of toasted soy flour (Wilding, 1969).

Although one would expect a low PER in the spun fiber because these fibers are obtained from the isolated soy protein which is already low, analogs made from spun fibers in combination with egg and other protein binders yield a nutritionally good material. Thulin and Kuramoto (1967) reported PER's for the finished analogs to range from 2.2 to 2.4.

Based on the observed PER's of the meat analogs in rat feeding studies, it would appear that we are obtaining products closely approximating the nutritional value of meat. PER is only one measure of nutritional value. There are also the values of vitamins and minerals to be considered. In his evaluation of the synthetic foods, Bauermann (1969) pointed out that he feels the Achilles' heel of these foods is their nutritional value. He felt at the present time it is technically impossible for a synthetic food to duplicate nutritionally a natural food. His assumption is based on belief that there are unknown growth factors present in natural foods. Some proponents of the synthetic foods feel that these unknown factors are minor and, therefore, of little practical value.

SUMMARY

Soy protein products are used as additives in comminuted meat products not only to extend these items and lower cost, but also to use their several functional properties to produce tasty meat preparations. Their use in federally inspected meat processing plants is regulated.

Soy proteins as additives or modified into meat analogs are being used to satisfy the needs of various diet conscious consumers.

Two types of meat analogs are produced from basic soy protein products: those composed primarily of spun fibers and those formed through the thermoplastic extrusion process.

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Received for review November 14, 1969. Accepted July 6, 1970. Presented at the Division of Agricultural and Food Chemistry, 158th Meeting, ACS, New York, N.Y., September 1969.