Oilseed Protein Concentrates and Isolates[1]

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ABSTRACT

Much attention has been focused on the oilseed crops as an alternate and largely untapped source of food protein in an endeavor to provide needed nourishment for large segments of the world's expanding population. A significant part of this attention has been devoted to the practical concentration and isolation of the proteins of several oilseeds. As a result of intensive effort during the last decade, soy protein concentrates and isolates are now commercial commodities which are gaining increasing acceptance as useful functional and nutritional ingredients for food. This report is concerned with a brief review of the commercial processing, product characteristics and food utilization of soy protein concentrates and isolates. In addition, pertinent comments on the concentrates and isolates of other oilseed are included.

INTRODUCTION

In the last several decades, increasing attention has been focused on the oilseed crops as an alternate, and largely untapped, source of food protein. This attention has resulted from the grave concern over the lack of adequate protein to provide needed nourishment for large segments of the world's population in the years ahead. Certainly the long history of the use of the soybean for food in the Orient, the development of a number of oilseed meals for the improved feeding of livestock and poultry, and the increasing production of oilseeds, world-wide, provide ample justification for this attention. A 1968 report to the United Nations stressed the need to increase the direct food use of oilseeds and oilseed protein concentrates by the human population (1).

It is recognized that the continuing problem with oilseeds is that their main contribution to food tends to be in the developed countries rather than in the lands of origin (2), often where the dire protein needs exist. An FAO publication (2) indicates that about 63 million tons of oilseed, which corresponds roughly to about 30 to 40 million tons of potential human food, are currently used for oil production with the defatted residue going into animal feeds, fertilizers and other nondirect or nonfood uses.

In more recent years, it has been demonstrated amply that oilseed protein products will be used for food only if they can be presented in appealing and acceptable food forms. Within the last 10 years or so, special attention has been devoted to concentrating and isolating the proteins of oilseeds since such concentrates and isolates offer a greater opportunity for incorporation in and supplementation of a broader variety of foods of various food cultures, and may, particularly, fit the needs of infants whose food intake is limited and whose protein need is critical.

This report is concerned with a brief and selective review of the current commercial processing technology, commercial product characteristics and food utilization patterns of soybean protein concentrates and isolates. A full review of progress in the development of technologies for the production of protein concentrates and isolates from other oilseeds, including peanut, cottonseed, coconut, sesame, sunflower and rape, among others, is not within the scope of this discussion. Although each oilseed has certain unique characteristics of both technical and economic natures, there are factors common to all oilseeds in their utilization for the production of concentrates and isolates. Certain of these factors will be noted in this review.

PROCESSING OF OILSEED PROTEIN CONCENTRATES AND ISOLATES

Source Material

The selection and handling of oilseeds from farm to the processing facility are obviously important factors in producing wholesome food-grade products. For the production of soybean protein concentrates and isolates, it is customary practice in the U.S. to employ No. 1 or No. 2 yellow soybeans. Bean selection is facilitated by the USDA grading system (3,4). In contrast to earlier practices for the production of feed-grade meal, more attention is paid to bean selection for manufacture of food-grade flours, grits, concentrates and isolates. Important bean quality factors include grade, removal of foreign matter of field origin including deleterious weed seeds, and controlled storage to prevent deterioration and infestation by microorganisms, insects and rodents (5). The contamination of oilseeds and oilseed cakes or meals by mycotoxins is a serious problem which has received much attention. A recent study indicates that there is little evidence of aflatoxin in soybeans moving in commercial channels in the U.S. (6). Other oilseeds such as peanut and cottonseed have shown a more serious problem in this regard. Nonetheless, in utilizing all oilseeds for the production of food- and feed-grade protein products, there must be concern with establishing harvesting, storage and processing procedures for the reduction and prevention of microbial contamination.

In the production of defatted raw material for the commercial processing of soy protein concentrates and isolates, sound, clean beans are cracked, dehulled, tempered with moist heat, and then flaked, as shown in Figure 1 (7,8). The flaked beans are extracted in countercurrent systems with a "hexane cut" of petroleum hydrocarbons. The defatted flakes are then desolventized (9). These basic operations have become well established over the years in the soybean crushing industry. Today more attention is given to sanitary plant design and to sanitation control in providing wholesome raw material for the production of the protein concentrates and isolates. Properly processed and properly handled defatted flakes are free of pathogenic organisms and possess low standard plate counts, usually less than 50,000 organisms per gram (10). Obviously, low microbial load is desirable in the wet processing of concentrates and isolates wherein the organisms can multiply rapidly. The separation of bean hulls provides a more concentrated protein source and eliminates a source of mucilagenous material which can detract from protein quality (11). This processing stage must be considered in dealing with other oilseeds wherein the seed coat constitutes a much larger portion of the seed and often contains substances affecting both process efficiency and product quality. Minimal exposure of the defatted flakes to moist heat during desolventizing is necessary in order to retain high protein solubility for ready isolation (11). This

[1]One of 21 papers presented at the Symposium, "Oilseed Processors Challenged by World Protein Need," ISF-AOCS World Congress, Chicago, September 1970.

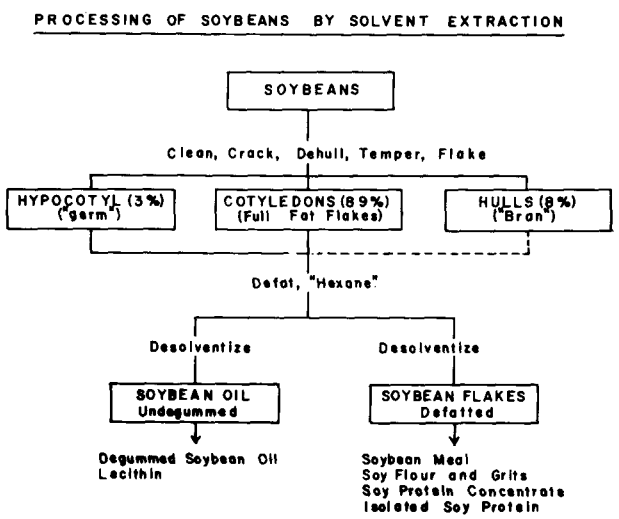

FIG. 1. Processing of soybeans for the production of soy protein concentrates and isolates.

becomes less critical if the defatted raw material is intended for the production of soy protein concentrates.

Soy Protein Concentrates

Soy protein concentrates are defined as products containing a minimum of 70% protein (Nx6.25) on a moisture-free basis. These concentrates are commercially produced by three basic processes which differ as to the means utilized to immobilize the major protein fraction of the defatted flakes or flour during extraction of the sugars, soluble nitrogenous matter, mineral matter and other minor constituents (12,13) (Fig. 2). In one process, the lower molecular weight material is extracted with water acidified to about pH 4.5, the average isoelectric point of the major soybean globulins. This process results in a greater loss of nitrogen since a number of minor proteins are soluble in water at pH 4.5. Because of the acidic nature of the resulting product, the leached material is often neutralized with food-grade alkali prior to drying. In another process, the sugar fraction is separated by leaching the defatted raw material with 60% to 80% aqueous alcohol. In a third process, the defatted flakes or flour are denatured by moist heat and then extracted with water. It has been reported that the yield of dry concentrate from each of these processes is about 60% to 70% of defatted flake weight.

The products of all three processes are similar in the gross compositional characteristics which define a soy protein concentrate (Table I). The products produced by the aqueous alcohol and water leaching processes have low nitrogen solubility because of protein denaturation; by

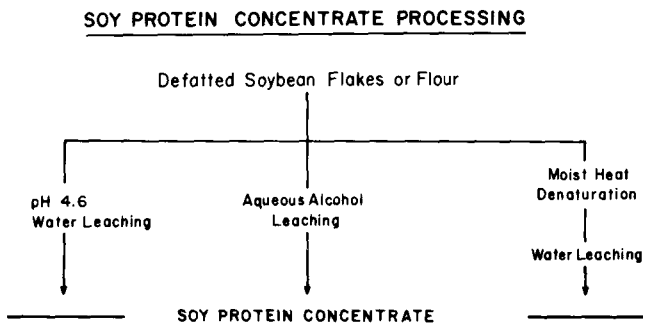

FIG. 2. Processes for the production of soy protein concentrates.

solvent in the first instance and moist heat in the second. In contrast, the product resulting from aqueous acid leaching has higher nitrogen solubility, but only if it is neutralized prior to drying. These concentrates may vary as to color, flavor, particle size and water and fat absorption, all characteristics which are important in food manufacture. The concentrates have improved flavor characteristics as compared to commercially available soy flours. One reported study indicates that an aqueous alcohol leached product has better flavor characteristics than does an aqueous acid leached concentrate (14).

Cottonseed Protein Concentrates

Progress has been made in developing processes for the commercial production of protein concentrates from cottonseed or defatted cottonseed meal of the glanded or glandless varieties. In one process, cottonseed is defatted and enriched in protein using hexane in a liquid cyclone process (LCP) (15). This process results in a product having a materially-reduced level of gossypol, the nutritionally undesirable pigment of glanded cottonseed. A recent report indicates that a semicommercial unit utilizing the LCP system has been in operation at Hubli, India, and that a commercial-scale LCP unit will be constructed in the U.S. (16). A process employing high energy milling and air classification of defatted glandless cottonseed meal to obtain products of higher protein content has also been described (17).

Soy Protein Isolates

Although the basic principles of protein isolation from the soybean were established many years ago with foundations which reach back into oriental antiquity, food-grade isolates have been commercially available in the U.S. for only about 10 years. More recently, there are reports of commercial production in Japan and Brazil.

The basic elements of protein isolation from defatted

TABLE I

Proximate Analyses of Commercial Soy Protein Concentrates and Isolates

	Concentrates			Isolates			
Analysis, %	A	B	C	A	B	C	D
Moisture	6.7	5.2	3.1	4.7	6.4	7.6	3.7
Protein (Nx6.25)	66.2	6.73	69.6	92.8	92.2	92.9	94.7
Protein, mfb[a]	70.9	71.1	72.2	97.4	98.7	100.0	98.4
Fat	0.3	0.3	1.2	---	---	---	---
Crude fiber	3.5	3.4	4.4	0.2	0.1	0.1	0.2
Ash	5.6	4.8	3.7	3.8	3.5	2.0	2.7
NSI[b]	5	69	3	85	95	---	---
pH (1:10 aqueous dispersion)	6.9	6.6	6.9	7.1	6.8	5.2	5.5

[a]Moisture-free basis.

[b]Nitrogen solubility index.

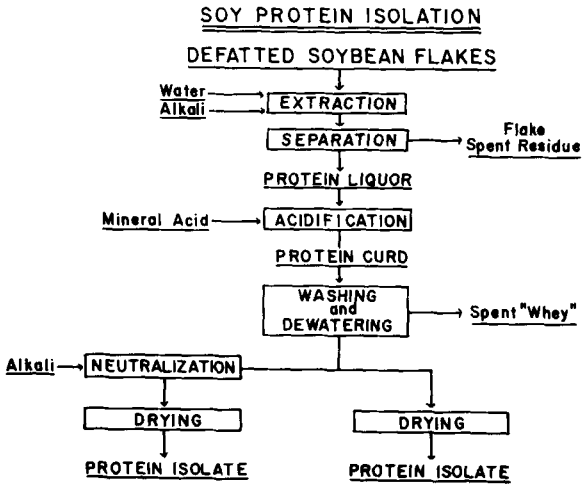

FIG. 3. Process for the production of soy protein isolate.

soybean flakes are relatively simple as shown in Figure 3, and are well documented in the literature (11,17,18). Defatted flakes are extracted with an aqueous medium which may vary in pH from near neutrality to moderate alkalinity. Extraction variables such as particle size, liquid-solids ratio, pH, agitation, temperature and time are selected to give optimum efficiency in processing (17). The protein extract is separated from the insoluble flake residue by appropriate mechanical devices. The clarified extract is then acidified with food-grade acid to a pH of about 4.5 to precipitate the major globulin fraction as a finely divided white curd, following which the curd is separated from soluble substances and washed to improve the purity of the protein. The concentrated washed curd can either be dried as such or neutralized to about pH 7.0 with food-grade alkali and then dried. These isolates are usually spray dried. The yield of soy protein isolates has been reported to vary from about 30% to 40% of the defatted flake weight (18).

For the production of oilseed protein concentrates and isolates, primary consideration must be given to sanitation in process design and equipment, and to sanitary operating procedures. In addition, this must be supplemented by properly designed process and product quality control programs to insure the production of wholesome food-grade materials.

Isolated soy protein has been defined as a product containing not less than 90% protein (Nx6.25) on a moisture-free basis. The isolates possess a low flavor intensity as compared to soy flours. The proximate analyses of several commercial isolates appear in Table I. All possess high protein and low crude fiber contents indicative of good protein extract clarification and curd separation. Two of the isolates, A and B, are in the neutralized form and hence are water dispersible. The others, C and D, are in the isoelectric form. At present, the dispersible type of isolate is the most important commercially in the U.S. because of its ready incorporation into wet food systems.

TABLE II

Essential Amino Acid Composition of Commercial Soy Protein Products[a]

Amino acid	Defatted soy flour	Soy protein concentrate	Soy protein isolate
Isoleucine	4.6	4.9	4.8
Leucine	7.7	8.0	7.8
Lysine	6.2	6.2	6.0
Methionine	1.3	1.3	1.0
Cystine	1.2	1.6	1.0
Phenylalanine	5.3	5.3	5.5
Threonine	4.2	4.3	3.7
Tryptophan	1.4	1.4	1.3
Valine	4.9	5.0	4.8

[a]As grams of essential amino acid per 16 grams of nitrogen.

Isolates of Other Oilseeds

There have been numerous reports of progress in the development of food protein isolates from a number of oilseeds. Much effort has been devoted to the development of practical methods for the isolation of peanut protein, most notably in India (19). Indeed, certain reports indicate that commercial production has been initiated there. Significant strides have been made in developing practical schemes for the production of cottonseed protein isolates which possess different properties which may be of value in various processed food systems (20). In addition there is reported evidence of work on the isolation of protein from coconut (21), sunflower (22) and rapeseed (23,24). Whether these will reach commercial fruition and have an impact on existing food protein need and shortage, only time will tell.

By-Products of Processing for Oilseed Concentrates and Isolates

The retrieval and disposal of by-products generated in the production of soy protein concentrates and isolates is a serious factor in process economics. The solid by-products resulting from seed milling (11), and those arising from the drying of spent insoluble residues after protein isolation are not overly difficult to handle, but must be disposed of economically so as to improve the cost of operation. These have been used in animal feeds, principally in ruminant feeds because of their higher fiber contents.

The aqueous by-product streams arising in the leaching of concentrates or in the isolation of soy protein pose a more difficult problem (11). These leach liquors or "wheys" contain sugars, some protein, mineral matter and a number of minor bean components. Often these liquors or wheys contain only 1% to 2% solids, thus presenting a

TABLE III

Protein Efficiency Ratios (PER) of Soy Protein Concentrates[a]

Protein source, concentrates	Protein[b] %	PER values			Literature reference
		Unheated	Heated	Reference casein	
A	52.9	0.34	2.06	3.00	30
B	57.1	1.37	2.10	3.00	30
C	64.8	1.86	2.02	3.00	30
A	66.2	2.43	---	2.65	12
B	67.3	2.29	---	2.65	12
C	69.6	2.50	---	2.65	12

[a]Determined in weanling rats at 10% protein in diets fed for 28 days.
[b]Protein content (Nx6.25) on an as-is basis.

TABLE IV

Protein Efficiency Ratios (PER) of Isolated Soy Proteins[a]

Protein source	Protein,[b] %	PER values	PER reference casein	Literature reference
Soy protein isolates (unheated)	85.7-90.2	1.36-1.91	3.00	30
Soy protein isolates (heated)	85.7-90.2	1.46-2.29	3.00	30
Isoelectric protein	82.7	2.06	2.83	32
Ca-coagulated protein	83.9	1.94	2.83	32
Commercial soy protein isolate	93.8	1.97	2.83	32
Soy protein isolate	---	0.33	3.38	31
Soy protein isolate (heat treated)	---	2.44	3.38	31

[a]Determined in weanling rats at 10% protein in diets fed for 28 days.

[b]Protein content (Nx6.25) on an as-is basis.

major challenge in economic retrieval and disposal. Obviously, the problem grows with increasing production. The sugar-containing residues from soy protein concentrate production have been utilized in animal feeds since they contain useful caloric and proteinaceous materials. It should be stressed that in the utilization of any oilseed for production of concentrates or isolates, the question of by-product retrieval or disposal must be satisfactorily resolved. Another factor which cannot be overlooked is the need for a steady large volume supply of potable water for the aqueous leaching of concentrates or for the isolation of protein.

FOOD UTILIZATION OF SOY PROTEIN CONCENTRATES AND ISOLATES

Nutritional Value

The nutritional value of various soy protein products for food has been the subject of numerous investigations (25-27). In the main, these investigations indicate that properly processed and properly used soybean products provide a source of food protein of good biological value. These soy protein products provide all the essential amino acids, but are limiting in methionine. Table II presents the essential amino acid composition of a commercial soy protein concentrate and isolate as compared to that of a defatted soy flour. It is to be noted that the soy protein isolate has a lower content of the critical sulfur amino acids. This is a result of protein fractionation during isolation wherein only the acid-precipitable globulins of the soybean are recovered and further processed, and of process conditions (18,28). Adequately processed soy protein concentrates have demonstrated good protein efficiency ratios when compared to casein (Table III) (12,29,30). On the other hand, the reported values for soy protein isolates (Table IV) are lower and variable. There is evidence that proper heat treatment of the isolates is necessary to inactivate growth inhibitors and, perhaps, to improve digestibility and utilization in order to obtain maximal protein value (30-32).

For food, however, the nutritional value of the soy protein products, per se, is only part of the picture. Their value must be assessed in relation to the nutritional value of the finished food item as eaten. Processed foods, and normal diets for that matter (27), are often composed of several protein-containing products which may complement one another, and preparation of foods for the table often involves heat processing which can either increase or decrease their nutritional value.

Numerous publications describe the nutritional value of other oilseed protein products, most often that of the defatted meals or flours (26). In considering nutritional adequacy for man and animals, the matter of antinutritional substances or toxicants of endogenous nature has received much attention. This concern has prompted the investigation of a host of oilseed components including protease inhibitors, hemagglutinins, saponins, thioglucosides, goitrogens and pigments among others (33).

Soy Protein Concentrates

The current food uses of soy protein concentrates are: (a) processed meat products (sausages, luncheon loaves, patties, meat loaves and meat balls, and meat-in-sauce items); (b) bakery products (white bread, biscuits and buns, cakes and cake mixes); (c) breakfast cereals; and (d) dietary wafers. It is estimated by Hammonds and Call (34) that these concentrates are being used for food in the U.S. to the extent of 33 million lb/year. The concentrates have, in general, better flavor characteristics than soy flour and grits. In addition, they provide important functional characteristics such as moisture absorption, juice-holding and fat-binding properties, and contribute to textural properties. These qualities together with good nutritional properties at reasonable cost make the concentrates valuable additives in comminuted meat items including meat patties, meat loaves, meat-in-sauce items, luncheon loaves, sausage and the like. Because of their reasonably high lysine content, the soy protein concentrates are a good source of complementary protein for the nutritional fortification of cereal grain foods including breads, cakes and related bakery items (27). It is expected that the oilseed protein concentrates may find increasing usage in contributing to the improvement of nutritional value of various cereal grain foods in both developed and developing countries (26).

Soy Protein Isolates

Since their commercial introduction in about 1960, the food-grade soy protein isolates are now being produced in the U.S. at a volume estimated to be in the range of 15 (18) to 38 (34) million pounds per year. Much of the growth has been due to the functional properties which are of value in food design and food processing. These include, among others, solubility and dispersibility, emulsifying and emulsion-stabilizing actions, fat and moisture binding, gelling and fiber-forming (35). The following listing of the current food uses of soy protein isolates underscores this fact: (a) processed meat products (sausages, luncheon loaves, canned luncheon loaves, and poultry rolls and related items); (b) textured meat-like analogs (spun fiber) (bacon-like bits, and simulated beef, ham and chicken chunks); (c) dairy-type foods (whipped toppings, coffee whiteners, frozen dessert, and beverage powders); (d) beverages (fruit-flavored beverages); (e) special dietary items (infant formulations, and dietary beverages and foods). It is logical to consider that,

in time, new generation isolates with improved specific functional properties designed for current and new volume uses will be introduced.

In spite of the need for functionally active protein food ingredients, the nutritional value of these soy proteins cannot be ignored in food design and becomes of paramount importance in those foods which either contribute, or are designed to contribute, in a significant way to the daily intake of dietary protein. In the last several years, three improved hypoallergenic infant formulations have appeared in the U.S. market place (36). These are all based upon soy protein isolate as the source of protein. Since these products are often the sole source of dietary protein, the protein is supplemented with an appropriate amount of methionine. A number of publications have described the supplementary nutritional value of isolates in bread and meat products (18,37). Several reports attest to the good nutritional value of a composite meat-like food wherein spun soy protein fiber affords the textural matrix (31, 38). In recent years there has been considerable activity and interest in protein beverages, both liquid and powder for reconstitution (39). Several market introductions of bottled soy protein isolate-based beverages have been made in a protein-short area overseas. In India, peanut protein isolate is being used in infant foods and for the toning or extension of milk.

Pricing of Soy Protein Concentrates and Isolates

In spite of rising costs in the U.S., there have been no recent major changes in the pricing of the basic soy protein products; the concentrates sell for about 18 to 24 cents/lb and the isolates for about 35 to 40 cents/lb. It is difficult to foresee any downward change in this price structure in the near future.

Understandably, the cost per unit of nutritious protein is important in feeding the hungry people of the world. However, this must be tempered with the realization that this protein must be offered in appealing food forms which are acceptable in the target food culture. Obviously there is still much to learn about the use of vegetable proteins, including oilseed concentrates and isolates, in making foods which generate and maintain consumer acceptability, and about the marketing of these foods in both developed and developing countries.

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