Oilseed Vegetable Protein Concentrates

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ABSTRACT

Soy protein concentrates are articles of commerce in the U.S. and other areas of the world. The procedures for producing these products involve processes where the protein is "immobilized" by various procedures, whereby soluble materials such as carbohydrates, mineral matter, and other water or alcohol soluble constituents are removed. There have been four general procedures which have been used commercially, but recently a fifth procedure involving what might be referred to as a "triple" solvent procedure has been developed. While the commercial products available, at least in the U.S., are from soy, development work has been carried out to produce concentrate products from peanut, sunflower, sesame, and rapeseed. However, there are no commercial installations for producing protein concentrates from these oilseeds. A brief discussion of the various processes is presented.

Originally, this paper was to be a discussion of soy protein concentrates, but the request was made that the presentation be broader and include information on oilseed protein concentrates in general. For practical purposes, at least in the U.S., the only commercially available high protein oilseed vegetable protein concentrate products are from soy. There is work being carried out in various government, university, and some private laboratories on other vegetable materials for possible use as protein concentrates.

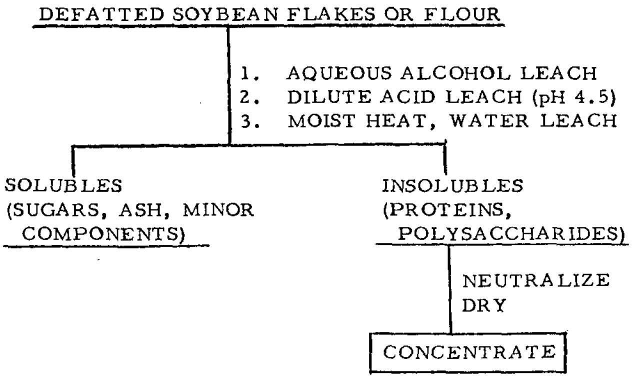

FIG. 1. Processes for preparing soybean protein concentrates.

In the U.S., the commonly accepted definition for soy protein concentrate is the product that is prepared from high quality, sound, clean, dehulled soybeans by removing most of the oil and water soluble nonprotein constituents and that shall contain not less than 70% protein (N x 6.25) on a moisture-free basis. Logically, the definition of an oilseed protein concentrate could be the product prepared from high quality, sound, clean, dehulled oilseeds by removing most of the oil and water soluble nonprotein constituents, with the protein content set at some minimum level, depending on the oilseed involved. It is also possible to prepare certain types of protein concentrate from grain products where the fat may or may not be removed, but certain carbohydrate materials may be separated to give relatively high protein concentrates. Concentrates may be prepared by air classification of ground materials. Since the major interest at this Conference deals with oilseeds, the discussion will not cover cereal protein concentrates.

There are several reasons for the development of soy protein concentrates, including improved flavor over conventional defatted soy flour and grits, the desire for higher protein content for such products to be used as ingredients in formulated foods, to remove certain oligosaccharides which may be undesirable for some food applications, and for improved color.

While there are a number of ways by which protein concentrates may be produced, the commercial processes begin with defatted material, which may be a flake, grit, or flour and which may have had varying amounts of heat treatment before being processed further to produce the concentrates.

In the procedures being used, the soluble sugars (sucrose, raffinose, and stachyose), some mineral constituents, and other water or alcohol soluble constituents are removed by a leach process. For a rough figure, oligosaccharides make up about half of the total carbohydrates in defatted soy flakes, and the other half consists of water insoluble polysaccharides.

Figure 1 shows a general flow sheet for three of the processes currently being practiced (1).

In the aqueous alcohol process, the defatted soy material is subjected to extraction by aqueous alcohol with ethanol concentration usually in the range of 50-70%. Due to the

TABLE I

Proximate Analyses of Soy Protein Concentrates[a]

	Manufacturing process		
Property or constituent	Alcohol leach	Acid leach	Moist heat, water leach
Nitrogen Solubility Index	5	69	3
pH of 1:10 water dispersion	6.9	6.6	6.9
		Percent	
Protein (N x 6.25)	66	67	70
Moisture	6.7	5.2	3.1
Fat (petroleum ether extractable)	0.3	0.3	1.2
Crude fiber	3.5	3.4	4.4
Ash	5.6	4.8	3.7

[a]As is basis (7).

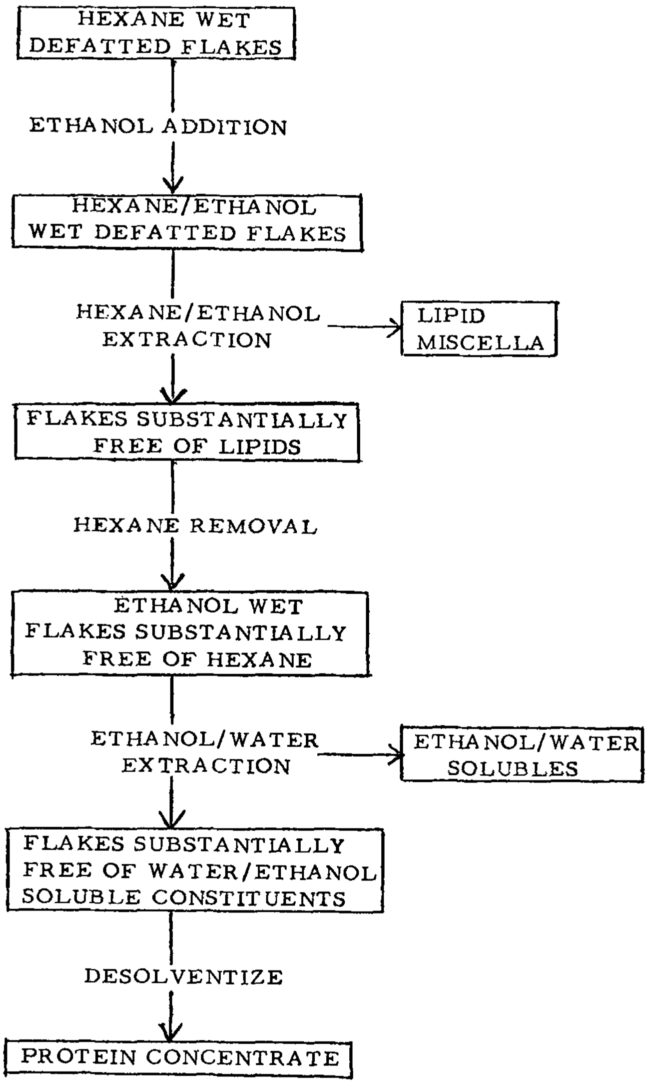

FIG. 2. Triple solvent process for production of soy protein concentrate (2).

innate denaturing effect of the aqueous alcohol, regardless of the water dispersibility of the protein in the initial starting material, the protein is denatured so that the water dispersibility of the protein in the finished soy protein concentrate is rather low, with a Protein Dispersibility Index (PDI) in the range of ca. 10. PDI and NSI (Nitrogen Solubility Index) are terms used to express the percentage of total protein in a given product which is dispersible in water using standard analytical procedures.

In the aqueous acid leach process, the pH of the water and flake material is adjusted to ca. 4.5 to immobilize the protein and allow for extraction of the other solubles.

In the third process, the soy material is heated in the presence of moisture to immobilize the protein by heat denaturation, followed by water leaching.

Table I shows the proximate analyses of soy protein produced by the above procedure (1).

If the defatted flake material is analyzed by conventional procedures, generally the "free" fat in the solvent extracted flakes will be in the range of 1% or lower. However, there is a substantial amount of fatty material present in such solvent extracted flakes which is bound to the protein or other constituents. Although the procedures, as described, do result in improved flavor characteristics when compared to conventional defatted soy flour and grits, this residual fatty material still contributes some flavor and may affect the flavor stability of these products on storage. Further, the bound fats may have an effect on the functional characteristics of the concentrates when used in certain food applications.

Another procedure (2) has been developed using a triple solvent system to produce soy protein concentrate products with better flavor and functionality. A flow sheet for the triple solvent process is shown in Figure 2. With this procedure, one obtains higher phosphatide removal and recovery. In this process, the beans are submitted to the usual procedures of dehulling, flaking, and solvent extraction, but the hexane wet flakes are submitted to a further treatment with ethanol in the presence of hexane to remove more of the residual lipid material.

The ethanol/hexane wet flakes are hexane desolventized to remove substantially all of the hexane, and the alcohol wet flakes are further subjected to an ethanol-water extraction to give a flake material essentially free of water soluble constituents and relatively low in total fat content. The flakes are then desolventized, resulting in a low flavored, essentially white soy protein concentrate product.

Depending on the procedure used to produce the soy protein concentrates, the nature of the protein and its composition in the resulting products will be somewhat different. In the alcohol leach process and the water leach process of heat denatured flakes, very little proteinaceous material is lost in the water phase. In the acid leach process, depending on the initial PDI of the starting raw materials, there is a significant loss of the albuminous type proteins in the extract. As a result, the nutritional value of the protein from the acid leach process is somewhat lower than in the other two processes. However, since the acid leach process can result in a product with a higher PDI, concentrates of this type will have more desirable functional characteristics in certain food applications. All of the soy protein concentrates, regardless of process used, do have certain water and fat-holding characteristics, whereby they find application in comminuted meat products. From the flavor standpoint, the alcohol washed material, by either of the processes described, will generally have better flavor than the acid leach product.

Since the product from the triple solvent process is new and not yet available commercially, although it will be soon, at this point it is difficult to make a direct comparison of the products from the two alcohol leach procedures. Based on known scientific evidence, it is probable that the triple solvent process will give a superior product flavor and color in comparison to the usual aqueous alcohol leach products currently on the market.

Another procedure which has been used in Japan to produce soy protein concentrates consists of slurrying the flake or flour material at ca. 10 times the wt of water to soybean meal, followed by the addition of calcium sulfate or organic acids to precipitate the proteins, filtration or centrifugation of the mixture to remove the whey, and drying the insoluble materials. They claim that the so-called "beany" and "bitter" flavor is removed in the whey portion (3).

One of the important considerations of any of these processes is the disposal of the water soluble constituents. For approximate purposes, the whey resulting from the production of 1 ton of soy protein concentrate is about equivalent to a population of 5,000; therefore, whey disposal is an important consideration. In some cases, the producers of the soy protein concentrates are evaporating to concentrate the whey. This concentrated product is being used in animal feed by selling directly to feed mixers or by addition to meal being sold for animal feed.

Soy protein concentrates of the various types are being used in comminuted meat products, dry breakfast cereals, special dietary foods, calf milk replacers, to produce textured soy protein products, etc.

There has been a great deal of discussion regarding the nutritional quality of the protein of soy products and factors which influence nutritional value. It is well established that, for most animal feeding purposes, it is desirable

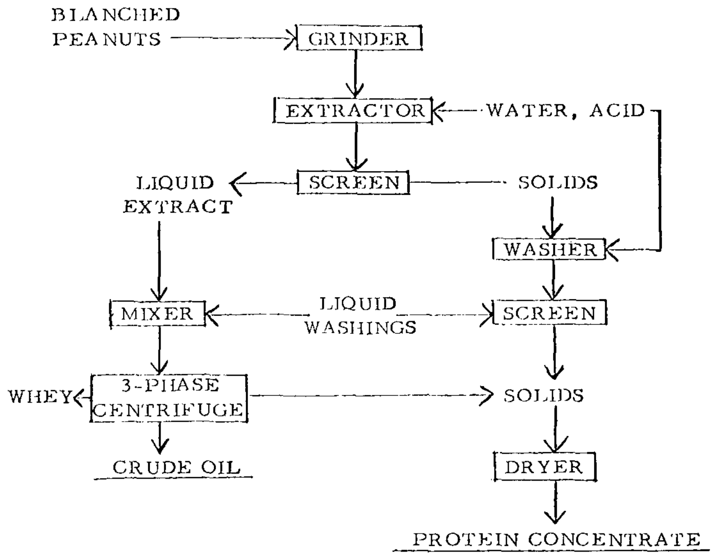

FIG. 3. Simplified flow chart for the aqueous processing of peanuts (concentrate procedure).

to heat process soybean meal to such a point that the antitrypsin factor is essentially destroyed. It apparently is not necessary to have 100% destruction of antitrypsin to obtain optimum nutritional value from the protein in conjunction with other proteins in the feed. In the production of edible soy protein products, such as soy protein concentrates and others, in order to have desirable functional characteristics, many of the edible soy protein-containing products are not heat processed to such an extent as to completely destroy the antitrypsin factor. In most foods where soy protein concentrate would be considered, the mixture of ingredients used to produce the finished food product would usually be heat processed sufficiently to destroy the antitrypsin factor in the further processing operation. There is some question as to the importance of antitrypsin factor insofar as the human is concerned. There is evidence that human trypsin is different from trypsin in other animals and may not be inactivated in the same way or to the extent that may be the case with other animal trypsin. Besides destruction of the antitrypsin, destruction of urease activity is desirable if meal is to be used in animal feeds containing urea. In livestock feeding it appears that the use of heat renders the protein more digestible.

Flavor is of major importance in the utilization of any ingredient in a food. Many soy products do have flavor characteristics which have limited their use in foods from the standpoint of quantities of soy products which might be used as ingredients and perhaps whether any may be used at all in certain applications to produce a desirable acceptable food product. While there are a number of constituents in the soybean which are responsible for the flavor of a soy product, as indicated above, some of the components may be removed by water and alcohol to give flavor improvement. There are many components which have been isolated from various soy products which are known to have undesirable flavors, such as saponins, certain carbohydrate principals, and fatty materials. It appears that the enzyme lipoxygenase, in the presence of oxygen, results in enzymatic oxidation of certain fatty materials to produce a wide variety of chemicals known to have undesirable flavor characteristics. The ideal situation would be a process whereby lipoxygenase could be destroyed in the whole soybean before further processing. Studies have been carried out that show that, if the lipoxygenase is destroyed before the bean is ruptured in any manner, products produced from beans so treated are definitely improved in flavor over products produced by the conventional means where lipoxygenase is free to give reactions which produce many of these undesirable chemicals. While many of these components can be removed by alcohol and water, it would be ideal to process in such a way that these chemical components would never be produced originally. Further, there is evidence that certain of the phosphotidyl material can undergo autooxidation, without enzymes being present, resulting in undesirable flavor. The removal of any of these components which may give flavor problems later in finished products would be highly desirable.

Soy protein products can be produced in the laboratory which are practically flavor free, so it appears that the flavor problems are the result of components other than the protein.

In the various processes for producing soy protein concentrate, the nature of the starting raw material, the ratio of solvent to solids, pH control, technique of dewatering, time of neutralization, final neutralization, pH, method of drying, temperature control during drying—all will be factors contributing to the nature of the finished concentrate. In some cases, the composition of the water used in the extraction could also be a factor. Most of the processes in operation today are based on continuous extractions and continuous processing thereafter.

The general processes as described could probably be applied to most any oilseed with modification. It is known that, while there are similarities in the physical chemical properties of proteins from the variety of oilseeds, there also are some marked differences.

Other processes have been developed to produce certain types of oilseed protein concentrates by aqueous processing. Texas A&M University has developed an aqueous extraction process to separate the oil and protein-containing constituents from peanut and coconut (4). However, the protein portion does contain some fat. In the process, a type of concentrate or isolate can be produced, depending on the processing procedure. The efficiency of their process depends on how the products are ground, solid-liquid separation, centrifugation, demulsification, and drying of the products. A flow diagram of the process is shown in Figure 3.

In the case of peanuts, the grinding procedure is important. If the product is ground too fine, there is a problem of emulsification which makes demulsification difficult. If grinding is not sufficient and properly done, there would be loss of oil in the residue. Grinding may be carried out either wet or dry, depending on the oilseed being processed. The choice between wet or dry grinding will depend on the initial moisture content, chemical composition, and physical structure of the oilseed. Peanuts are best ground dry.

The extraction step is carried out by dispersing the ground seed particles in water and agitating the dispersion to enhance the extraction of the constituents. Factors influencing the efficiency are solids:water ratio, the types of salts present and their concentration, pH, extraction time, temperature, degree of agitation, and centrifugation equipment.

Because of the rather high percentage of solids in the dispersion, removal of the major portion of the solids has been found necessary to obtain efficient recovery of oil by centrifugation. The solids may be removed by filtration through vibrating or pressing type screens or by centrifugation. The solids may be subjected to washing procedures and further screening, with the finally washed product dried to give a concentrate. The liquid fraction is passed through a three phase centrifuge to give a whey product, a crude oil, and additional solids which are added to the solids going to the dryer. When problems arise from demulsification, the emulsion may be broken by a phase-inversion technique in which clear oil is added to the emulsion. With the aid of shear, at elevated temperature, it is claimed that nearly all of the oil can be freed by this procedure. This technique requires control of pH and reduction of moisture content below a certain critical level

TABLE II

Material Balance of Products from the Aqueous Processing of Peanuts[a]

Product	Concentrate procedure		
	Dry wt (kg)	Oil (kg)	Protein (kg)
Oil	40.4	40.4	0
Concentrate	38.6	3.2	25.1
Whey solids	7.2	1.1	1.6

[a]Based on 4.5% moisture content; 100 kg blanched peanuts contain 45.4 kg oil and 27.2 kg protein (N x 5.46).

to break the emulsion. It is claimed that the oil is of high quality and water washed product requires little, if any, further treatment, except for removal of water by centrifugation or vacuum drying.

The removal of water from the protein is usually done by spray drying.

By modification of this procedure, an isolated soy protein product can be produced if the extraction is carried out under alkaline conditions rather than acid conditions; the solids may be separated and washed, with the wash water being added to the liquid portion. The liquid portion is then acidified to the isoelectric point, followed by centrifugation or screening to remove solids. The solids may be washed and the liquid portion added to the liquid from the initial screening, followed by three phase centrifugation to give a solids fraction, crude oil, and whey. The solids from the three phase centrifugation are added to the solids from the screening, and the product is spray dried as is or neutralized and spray dried.

From pilot plant work, from 100 kg of blanched peanuts containing 45.4 kg oil and 27.2 kg of protein (N x 5.46) by this procedure, ca. 40 lb of oil was recovered, as oil, and ca. 39 lb of concentrate containing 55% protein and 8% oil. A material balance from the aqueous processing of peanuts is shown in Table II.

At the present time, a pilot plant is operating in the Philippines to produce coconut protein products from coconut meats using the process described, with modifications as necessary for coconut processing.

Another oilseed of interest is sesame. While most of the sesame seed produced in the world is processed to obtain oil, with the protein portion being of secondary interest and used primarily in animal feed, there is a substantial amount of sesame seed used directly as food as topping for breads and rolls, in confectionery items, and as a flavor in a variety of cooked foods. To produce an acceptable defatted sesame flour, it is necessary to use a different technology than that used in the conventional pressing operations. While direct solvent extraction of sesame seed is possible, the nature of the oil produced is different from that produced by a screw press operation and may not be completely acceptable by all oil users. Since sesame seed contains certain oxylate compounds, many feel that it would be desirable to remove the oxylate layer before the processing to edible products. This means that for human food the processing should be carried out on dehulled seed.

A dry technique for the production of sesame protein concentrates has been reported whereby the dehulled seed is defatted to produce a sesame flour with a protein content in the range of 60% (5). This may be higher or lower depending on the variety of seed used. By a mechanical classification, it is possible to obtain a protein concentrate containing from 65 to 69% protein, with another fraction having a protein content in the range of 43-46%. Using defatted sesame meal from dehulled seed, it may be possible to use a prepress operation which could be operated in a manner as to minimize protein denaturation, followed by solvent extraction to produce a good quality edible product for further processing by air classification or to be processed in a manner similar to those being used for producing soy protein concentrates.

Another oilseed which may be considered as a candidate for producing protein concentrates is sunflower. However, the major problem with sunflower is the presence of chlorogenic acid, which results in color problems for the finished flour. Work is being carried out at the University of Saskatchewan in Canada (6), where countercurrent extraction of sunflower flour with water, acid, or alcohol or countercurrent diffusion of sunflower seed with acid offers promise for removal of chlorogenic acid. With a five to six stage countercurrent procedure, they were able to extract ca. 90% of the chlorogenic acid at a solvent:flour ratio of ca. 6:1 (v/w), or from seed at a solvent:seed ratio of 3:1 (v/w). They obtained a sunflower protein concentrate containing ca. 70% protein with light color under alkaline conditions. Acid extraction of the sunflower flour produced a more soluble protein concentrate, but 40% of the flour solids and 25% of the flour protein were lost in the liquor or the extract. Acid extraction at 80 C or water extraction of protein denatured flour improved the rate of chlorogenic extraction, but protein losses in the extract still remained high. They found that aqueous ethanol was an efficient solvent for the removal of chlorogenic acid from the flour, and the protein concentrate yield of 77-78% accounted for 95-97% of the flour protein. They state that important factors in assessing the relative merits of the various processes are the need for the recovery of solvent in the alcohol process, the relative ease in handling the products during acid diffusion of the seed, and nitrogen solubility of the protein concentrates.

There has been a great deal of work on the possibilities of producing protein products from cottonseed, but the major problem has been the presence of certain toxic materials—namely, gossypol—in most cottonseed. Varieties of glandless cottonseeds are being produced which are essentially free of gossypol. While there are techniques which have been devised to remove gossypol and produce different types of cottonseed protein-containing products, thus far the processes have not been successfully worked out on a commercial scale.

Rapeseed is also an interesting possibility for producing a concentrate, providing efficient procedures can be developed for removing thioglucosides.

If one accepts PER (Protein Efficiency Ratio) as a valid measurement of protein quality insofar as the human is concerned, protein products from sesame and sunflower and possibly coconut protein could serve as a complementary protein to be used with soy to give protein-containing products with improved nutritional characteristics. The day will come when we will need protein from many vegetable sources. It would appear that, of the high protein-containing vegetable seeds, the soybean will remain the major ingredient, from the standpoint of availability of seed, economics, and less of a problem to process into acceptable finished food products.

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