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Expert group meeting on pre-investment considerations and technical and economic production criteria in the oilseed processing industry
Vienna, Austria 16 - 20 October 1972

REVIEW AND COMPARATIVE ANALYSIS OF OILSEED RAW MATERIALS AND PROCESSES SUITABLE FOR THE PRODUCTION OF PROTEIN PRODUCTS FOR HUMAN CONSUMPTION 1/

by

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SUMMARY 1/

REVIEW AND COMPARATIVE ANALYSIS OF OILSEED RAW MATERIALS AND PROCESSES SUITABLE FOR THE PRODUCTION OF PROTEIN PRODUCTS FOR HUMAN CONSUMPTION

by

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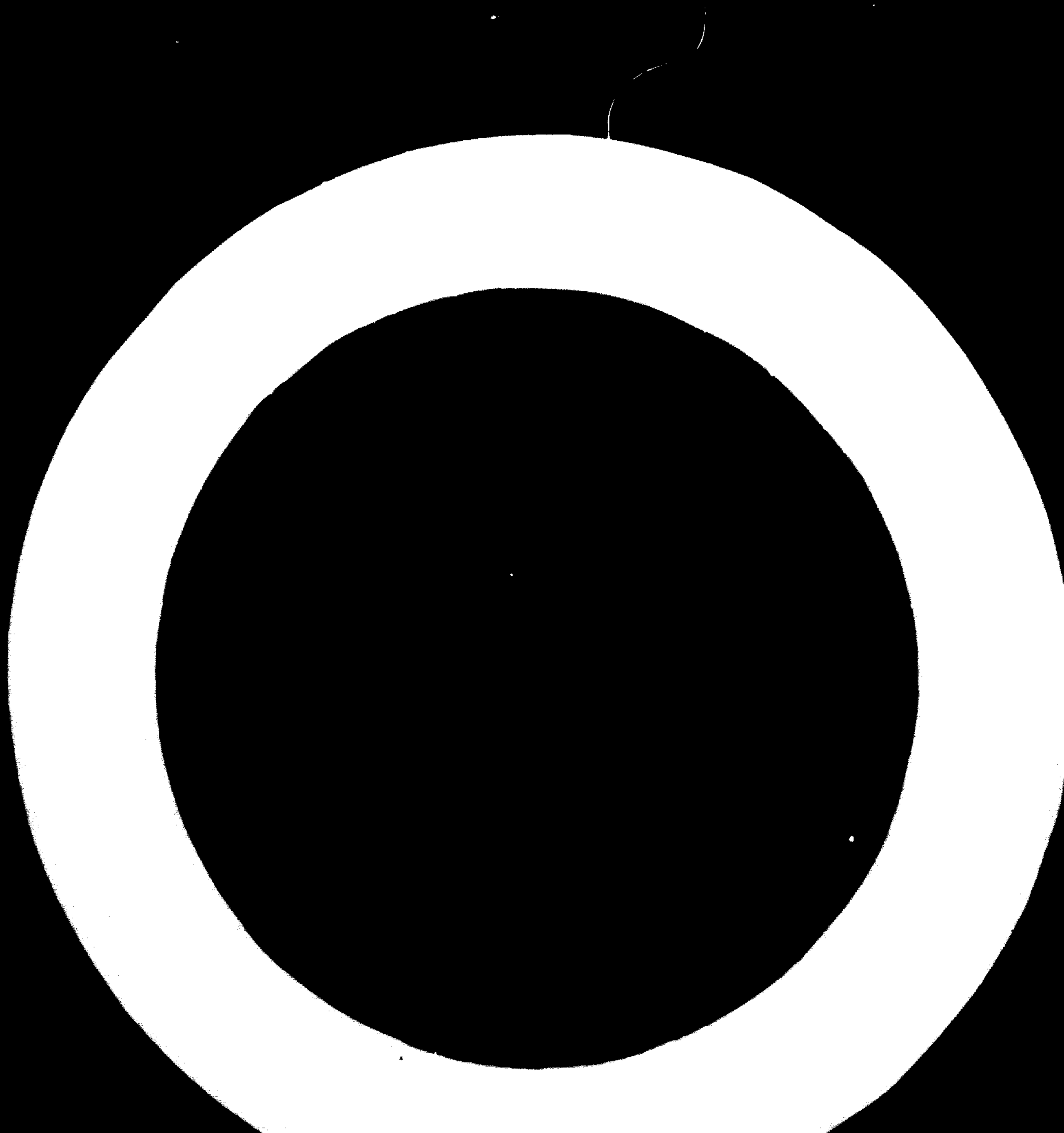

SUMMARY

With the steady increase in the number of people that the world's agricultural land must feed, it becomes evident that we must look to those agricultural crops that produce essential nutrients most efficiently for our survival. Oil and protein, two of the three major essential nutrients, can be produced with a high degree of efficiency via the oilseeds. The oils from oilseeds have made rapidly increasing contributions to our caloric requirements in this century. We are now faced with the critical need to look to the oilseeds as a direct source of protein in the world's foods.

"The potential of protein for humans from present production of oilseeds equals the amount of protein now supplied by animal sources."(2) The estimated world production of oilseed proteins exceeded 30 billion kilograms in 1971. Over half of this is produced as soybeans, chiefly in the United States, Mainland China and Brazil. Cottonseed, peanuts and coconuts represented about 8.5 billion kilograms of protein in 1971. Most of this protein was produced in developing countries where there is a chronic shortage of food proteins. Presently very little of this immediately available protein is being used directly as human food.

Each of the vegetable proteins has one or more limiting amino acids that restrict its utility in animal feeds and human foods if it is the sole source

of protein in the diet. Animal nutritionists have long recognized this and rely on blends of vegetable proteins, sometimes supplemented with minor proportions of animal protein or synthetic amino acids. This same approach can readily be applied to food systems.

A number of anti-nutritional factors have been indentified in several of the oilseeds. Technologies have been or are being developed for the successful inactivation or elimination of these factors. However, aflatoxin remains a major unresolved problem in the use of some oilseeds in foods.

It is important to recognize the differences in oilseeds and that these differences may represent opportunities as well as problems. Some of these differences are in color, flavor, ease of decortication and functional properties. Each of these can contribute favorably or unfavorably to the consumer acceptance of protein foods derived from the oilseeds.

A substantial amount of process technology has already been developed for the conversion of oilseeds into food intermediates. Most of this technology has been applied primarily to soybeans. Thus there are commercially successful processes for producing defatted oilseed flours, protein concentrates, protein isolates, fibrous products and beverages (soy milk). The opportunities in these areas for products other than those derived from soybeans has had much too little experimental attention and practically no commercialization to date.

For optimized economics there must be an initial separation of the oil from the oilseeds. Direct extraction with hexane has been widely applied to soybeans to recover as high a proportion of oil as possible. The defatted soybeans are then used as the raw material for the manufacture of the other types of products. With the other oilseeds it is commonly necessary to pre-press a substantial portion of the oil from the oilseed prior to hexane extraction. Because of protein denaturation, the extracted residues from the other oilseeds have reduced functional properties and are less adaptable to conversion to the several food intermediates. An aqueous centrifugal process for the quantitative recovery oil and undenatured protein products from oilseeds has been developed and applied successfully to fresh coconuts and to peanuts. On the basis of preliminary estimates, the protein products from this process are economically feasible and appear to have favorable functional properties. It is presently believed that the aqueous centrifugal oil milling technique can be applied to most or all oilseeds. An advantage of the aqueous processing is that this provides a suitable medium for the chemical attack on aflatoxin.

It is anticipated that the major food product areas where oilseed proteins will make significant contributions are those of meat-like products, beverages and protein fortified baked products (such as bread). For each of these applications it will be important to determine which of the oilseed products best serves the need as defined by availability, cost, nutrition and consumer acceptance. Because of the first two considerations, availability and cost, it would seem that the longe range strategy for the developing countries should be to concentrate their efforts upon the oilseeds they can best produce in their own countries.

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INTRODUCTION

It is interesting to reflect on the trends in the utilization of products derived from oilseeds during this century. At the turn of the century fats from animal origin, especially lard, tallow and butter, enjoyed a highly preferential position as food fats in those countries in the temperate climates. Because the vegetable oils were available in increasing quantities at comparatively low prices, there was a strong motivation to find a means for using the vegetable oils as alternates for the preferred animal fats. After the invention of hydrogenation, a shortening made entirely from cottonseed oil was introduced in the United States in 1911. At this point in time it is both amusing and amazing to recall that there were strong efforts to introduce legislation requiring that the hydrogenated vegetable oil shortening be labeled "imitation lard".

The invention of margarine dates back over one hundred years. The USA lagged behind Northern European countries in margarine technology in the early years of the century. Products were made that contained animal fats which resulted in rather unacceptable products that gave margarine a poor consumer image. In the 1930's the US manufacturers developed improved and highly acceptable margarines made exclusively from vegetable oils. They gradually overcome the poor image that had been created by the earlier products, gained in consumer acceptance and grew steadily in volume in spite of extensive legislative restrictions.

With the perceptive vision of hindsight, one can now see that the substitution of vegetable oils for animal fats was considerably more than simply a means to provide improved markets for the producers of vegetable oils. It is now apparent that it was a necessary trend in order to provide an adequate supply of food fats. The present world production of butter and lard is just slightly in excess of 8 million metric tons while that of edible vegetable oils and palm oils exceeds 27 million metric tons.[1]

Now the world is faced with the need to create protein food products that can serve as alternates for the traditional protein foods dervied from animal agriculture. The animal protein foods enjoy a tremendous popularity, but are very inefficient in their utilization of agricultural land. Consequently, their price is high and out of the reach of large masses of low income populations. As the amount of available agricultural land per capita decreases, the inefficiency of animal agriculture becomes a greater burden. Once again, the oilseeds offer a prime source of alternative protein foods. The food industries of the world have been working diligently, especially in the past decade, at the creation of alternate protein foods. As before, their primary motivation is the disparity in price between the proteins from oilseed sources and those from animal sources. A substantial amount of significant progress has been made and it is the purpose of this document to review that progress.

WORLD PRODUCTION OF OILSEEDS

As was stated very succintly in The World Food Problem, "the potential of protein for humans from present production of oilseeds equals the amount of protein now supplied by animal sources."[2] The estimated world production of oilseed proteins in 1971 is shown in Table 1. The production of over 30 billion kilograms of oilseed proteins is equivalent to about 28 grams of protein per person per day for 3 billion people. There are obvious fallacies in this kind of projection, but it does provide a perspective within which to consider the tremendous potential of a presently produced and available supply of low cost protein.

The data in Table 2 show the trends in production of oilseeds since 1960. Soybeans are outstanding, not only because they represent such a large proportion of the total oilseed crop, but also because of their spectacular growth over the past three decades and the favorable prospects for increased production. While cottonseed continues to maintain its second position, its future depends upon world demands for cotton fibers. Because it is a by-product, its production is less flexible than that of the other major oilseeds. Peanuts (or groundnuts) continue to maintain a strong third position. Both sunflower and rapeseed have been moving up rapidly in this period of time. The production of each can continue to be increased if there is a demand for their products at a price that will bring a suitable return to the producers. Sesame seed yields both an oil and a protein meal with desirable properties. However, its future production will probably continue to be inhibited by its lack of adaptability to mechanical harvesting. Coconut protein is a minor proportion of the world's total supply, but in a few countries, especially the Philippines and Indonesia, it could make a very significant contribution to the diet of the people of those countries. The protein represents a minor proportion of the coconuts and its future availability will be dependent entirely upon the world demand for coconut oil.

For those concerned with world food problems, it is important to consider not only the total world supply of the oilseeds, but also where each of them is grown. It is natural for a country with limited foreign exchange to prefer to use indigenous crops. Therefore, in the creation of new supplemental protein foods one should be concerned with the indigenous protein supply in the country of interest. In Tables 3 to 7 are shown the major producing countries of the principle oilseeds. From Table 3, it is apparent that the great preponderance of soybeans are produced in the United States and Mainland China. Brazil is rapidly becoming a major factor as a consequence of its very dramatic increase in soybean acreage over the past several years. Soybeans represent somewhat of a problem to international planners. Because the technology of soybean flours, concentrates and isolates has been so far advanced in the United States for a number of years, the preponderance of the food product development work that has been done in the past decade has been based on products derived from soybeans. Unfortunately, soybeans are not grown in many of the countries in greatest need of supplemental protein foods. It is possible that varieties of soybeans can be developed for production in the semi-tropical and tropical climates, but this may require a considerable sacrifice in per acre yield. Even in the United States the per acre yield of soybeans is considered to be only marginal in terms of being a satisfactory cash crop for a producer. Consequently, planners are faced with the prospect that, if they do develop acceptable foods based upon the products of soybeans, they may be committing themselves to an import program for which there is inadequate foreign exchange.

The geographic distribution of the production of cotton, and therefore cottonseed, as shown in Table 4, is much more favorable from the point of view of many of the developing countries. Presently cottonseed is very wastefully used in terms of potential human benefits. Only in India is there one small plant for the removal of gossypol from cottonseed to make it more suitable for use in human foods. A similar plant is presently under construction in the United States.

As shown in Table 5, the production of peanuts (groundnuts) is rather widely distributed among countries in the warmer climates. India is the world's largest producer of peanuts. They are produced in many countries of Africa and perhaps could be produced in all of the countries of Africa. Again, the protein meal from peanuts, as in cottonseed, is used in ways that make a minimum contribution to the human diet. Only in the United States are peanuts consumed principally as food. In other countries it is primarily produced for the recovery of oil and the highest use of the meal is as an animal feed. The peanut represents a tremendous untapped source of protein for human consumption whose production could be readily expanded.

The data in Table 6 show that the major producer of sunflower seed is the U.S.S.R. The other major producing areas are Southern European countries and Argentina. There is a substantial amount of interest in sunflower seed as a crop in the United States. The oil and protein products derived from sunflower seed are quite attractive and the only deterrent from its becoming a major oilseed crop is the economic return to the primary producer. The distribution of production of rapeseed is shown in Table 7. Note particularly the rapid increase in production in Canada. There are also reports of growing interest in Sweden. Major deterrents in the past to the production of rapeseed have been some components in both the oil and the meal that had undesirable properties. The oil contained substantial quantities of erucic acid which some nutritionists considered to be undesirable. Plant geneticists have developed varieties of rapeseed containing oil which is essentially devoid of erucic acid. This has substantially increased the commercial interest in rapeseed oil. Research in Canada and in Sweden appears to be overcoming the deficiencies of rapeseed meal. These will be discussed in a later section.

COMPARATIVE NUTRITIONAL VALUES OF THE PROTEIN OF OILSEEDS

As their name implies the oilseeds have been produced principally as a source of oil. The residue that remains after oil is removed by any of the commercial processes has commonly been used as a protein supplement in animal feeds. This relegation of the protein to a by-product status has kept the price low so that the defatted oilseeds constitute a source of very low cost protein.

It is beyond the scope of this document to review the tremendous amount of research that has been done on the nutritional quality of oilseed protein products. However, several general observations may be made from the mass of this research. First, it is generally recognized that proteins from vegetable origins do not have as favorable an amino acid balance for animal requirements as do proteins from animal sources. In comparison with animal proteins, each of the vegetable proteins has one or more limiting amino acids that restrict its utility in animal feeds and human foods if it is the sole source of protein in the diet. Animal nutritionists have long recognized this and rely on blends of vegetable proteins sometimes supplemented with minor proportions of animal protein or synthetic amino acids.

The long recognized supplemental effect of one vegetable protein upon another should not be ignored in planning human food systems. In evaluating the nutritional quality of any protein product, one should always keep in mind the other proteins with which it will be consumed and estimate the protein quality of the anticipated blend.

The data in Table 8 show typical analyses of the various oilseeds for protein, oil, crude fiber and ash. Soybeans are noteworthy in their high proportion of protein to oil. The world demand for protein supplements for animal feeds has accounted in large part for the tremendous growth in production of soybeans. As mentioned earlier, the supply of cottonseed is linked to the demand for cotton fiber. Because of the high ratio of oil to protein in the other oilseeds, their production will be dependent more on world demand for oil than for protein.

Typical analyses for the residues remaining after the oil has been removed from oilseeds are shown in Table 9. It should be pointed out that in all cases the oil content can be reduced to one percent or less by modern techniques of solvent extraction. There is an inverse relationship between the amount of crude fiber and the protein content. To a large extent the amount of crude fiber depends upon the success in decorticating the seed. The soybean processors have been markedly successful in decorticating soybeans so that they can produce a defatted meal containing no more than 3% crude fiber and approximately 50% protein. This technology is not as well advanced with the other oilseeds. Investigations of methods for the quantitative decortication of cottonseed for use in food products are presently underway at Texas A&M University and progress to date has been most encouraging.

Typical amino acid analyses of the protein of oilseeds are shown in Table 10. Note that the most common limiting amino acids are lysine, isoleucine and the sulphur-containing amino acids. There is really a rather remarkable similarity in the amino acid composition of the proteins of the oilseeds, which is perhaps not too surprising in view of the fact that they were all laid down by the plant to serve more or less the same physiological functions.

ANTI-NUTRITIONAL COMPONENTS OF OILSEEDS

A number of components have been identified in oilseeds that have undesirable physiological properties. These have been the subject of considerable research and a multitude of publications. One must be concerned with each of these when designing a process or food product based on oilseed proteins.

Aflatoxin is a problem common to all oilseeds as well as to all other food products. It has been the subject of a recent comprehensive review.[3] Obviously, the best way to attack aflatoxin is to prevent it. However, this is not always possible and may never be totally successful in hot, humid climates. Techniques for removing or destroying aflatoxin by solvent extraction or chemical action have been demonstrated, but none of the processes has yet been adopted for commercial use. Each of the methods reported to date has disadvantages, including denaturation of the proteins and destruction of some of the amino acids. This is an area where much more research is still needed.

The utilization of cottonseed in food products has been inhibited by the chemicals, particularly gossypol, found in the pigment glands of the seed. Gossypol and related compounds are quite toxic to monogastric animals, including man. However, the pigment glands can now be removed almost quantitatively from cottonseed meal by a liquid cyclone process. Such a plant it presently operating in India and another is under construction in Lubbock, Texas. In addition, plant geneticists have developed varieties of cottonseed which are devoid of the pigment glands. Several varieties are already in trial production in the United States and it is reported that a number of other varieties are ready for release. These glandless varieties could entirely eliminate the many problems associated with gossypol.

It has long been known that soybeans contain several anti-nutritional components, including a trypsin inhibitor, a goitrogenic compound, a diuretic and a hemagglutinin. Each of these is heat sensitive and destroyed during normal processing of soybean meal.[4]

Rapeseed contains glucosinolates which on hydrolysis yield toxic isothiocyanates. These are water soluble and a procession of diffusion extraction has been reported by the University of Saskatchewan.[5] It has also been reported that a group in Sweden has developed a detoxifying process which is ready for commercialization.[6]

OTHER CHARACTERISTICS OF OILSEEDS THAT CAN AFFECT THEIR FOOD USE POTENTIAL

Adequate nutrition for all segments of the world's population is a noble scientific objective. The creation of attractive, palatable, low cost protein foods is important to attaining that objective. The great mass of consumers, be they rich or poor, buy foods for gastronomic satisfaction rather than for nutritional balance. Therefore, while our objective may be good nutrition, our vehicle must be good food. Because of this, we must recognize certain food quality attributes that can favorably or adversely affect the successful use of oilseed proteins in foods.

One very practical consideration that has been largely overlooked is that of adequate decortication. For example, if the hulls are not quantitatively removed from cottonseed kernels, the flour and the concentrate made from these kernels will contain unsightly dark specks. While these may not be physiologically harmful, they are distinctly detrimental to the aesthetic appeal of any food products containing them. The new varieties of sunflower seed are especially difficult to decorticate. On the other hand, techniques are available for adequate decortication of soybeans and peanuts. Rapeseed probably represents a special situation where quantitative dehulling can best be accomplished after solvent extraction. For the broadest possible use of cottonseed, sunflower seed and rapeseed in food products, improved methods of decortication are essential.

Flavor is a most important characteristic and one about which very little is presently known with reference to the oilseed protein products. It is commonly agreed that extracted soybean meal has a strong characteristic flavor which is generally considered to be undesirable. This was one of the principle motivations for the creation of soy protein concentrates. In the production of soy protein concentrates and also the isolates, a substantial proportion of the characteristic soy flavor is eliminated. However, the original premise may not be valid for all food systems. While it is unquestionably true that soy flavor would be unsatisfactory in some food systems, it may be totally compatible with other food products. This is an area where there has been a serious deficiency of controlled experimentation to evaluate the flavor characteristics of oilseed protein products in a variety of food systems. Without question, the flavors of the flours and concentrates prepared from the different oilseeds vary substantially. What we need to know is how each of these products affects the flavor of a variety of types of foods.

Color is also important in a number of food systems. Often the color of the dry concentrate or isolate can be deceptive. For example, one made from glandless cottonseed may look quite white in the dry form, but when wet can become a rather unpleasant gray. Of course, this would only be pertinent in a food where whiteness is important. The proteins themselves are colorless, but are influenced by the numerous chromophoric or potentially chromophoric substances associated with them in the seed. One special problem is that of chlorogenic acid in sunflower seed that turns green to brown under alkaline conditions. This makes the preparation of a protein isolate from sunflower seed impossible by the traditional methods unless special precautions are taken.(7)

In the past several years there has been a growing awareness of the importance of recognizing the differences in the functional properties of proteins and protein food products. In using a protein product in a food, the manufacturer wants it to have certain specific properties. These will vary depending upon the nature of the food product and what he expects the protein to contribute to that food product. If it is used primarily for the purpose of providing added nutrition, then it should disperse in the food product without affecting the normal characteristics of that product. More commonly the protein is expected to provide some property, such as emulsifiability, whipability, gelation or texture. In any of these functional properties, protein products from the same source may vary depending upon the treatment they have received, and proteins from differing sources will vary because of the differing amino acid compositions and configurations. The literature on functional properties is still very sparse. It is commonly agreed that there is a need for some uniform, standardized functional property tests that bear some real relationship to usefulness in food systems. There are a number of tests being used, but there has been little or no demonstration that the results of these tests can be predictive of useful performance in foods. It is clear that proteins from the different oilseed sources do not behave alike in certain food systems, but at this point in our technology it is not known why they differ nor how to predict how they will differ other than to test them in the foods. This is an area where there is need for extensive basic and applied investigation.

FULL-FAT OILSEED FLOUR

There has been some interest in the past decade for a full-fat soy flour primarily for use in low cost protein foods in areas of protein under-nutrition. Figure 1 shows a process that was developed jointly by UNICEF, The Northern Utilization Research & Development staff of the U. S. Department of Agriculture and the Wenger Company of Sabetha, Kansas.(8)

The central step of the process is the cooking-extrusion in the Wenger apparatus. Dehulled soybean flakes are pre-conditioned with open steam injection, which raises the moisture content of the flakes to about 20% and elevates the temperature. The conditioned flakes are then put through the cooker-extruder, which has a residence time of less than one minute. This short time at maximum pressure and temperature minimizes damage to nutritional properties, but adequately inactivates anti-nutritional factors. The product is reported to have a mild flavor acceptable in some formulated food products.

PRODUCTION OF DEFATTED OILSEED FLOURS

For the production of oilseed meal or flour the oilseeds are commonly defatted by one of three methods: expeller, pre-press solvent extraction or direct solvent extraction. In the expeller process the oil is removed by mechanically squeezing the oilseeds at moderately high temperatures and pressures. The partially defatted residue of this process still contains 4 to 6% oil and the protein has been substantially denatured as a result of the high temperature. This limits, but does not preclude the use of expeller press-cake in food products. While the protein is denatured sufficiently to substantially reduce its solubility, the process can be controlled in a manner to retain most of the nutritional value of the protein. As with full-fat flour, this type of partially defatted flour can probably best be used in formulated products of the infant food or cooked cereal types.

Where adequate capital is available, the expeller process has been largely replaced by either direct solvent extraction or pre-press solvent extraction. The major use of direct solvent extraction has been with soybeans. Because of their relatively low oil content soybeans can be rolled into thin flakes from which the oil is readily extracted by hexane at a rate of percolation which permits practical continuous processing.

In the case of the other oilseeds with higher levels of oil in the kernels, direct solvent extraction becomes more difficult to entirely impractical. Evidently, the removal of the larger amount of oil results in a collapse of the structure of the meats causing poor percolation rates. With careful preparation cottonseed flakes can be solvent extracted. In order to improve the percolation, the hulls are not completely removed. It is a moot question whether cottonseed can be commercially extracted if all of the hulls were removed from the kernels.

Pre-press solvent extraction, which is applied to most of the oilseeds other than soybeans, is a two-step operation in which part of the oil is removed by an expeller or screw-press and the remainder removed from the press-cake by solvent extraction. It has some of the advantages and disadvantages of both operations. The principle advantage is economics. Because the marketplace has placed a value on the oil at two or more times that of the press cake, the oilseed processor is motivated to remove as much as oil as he practically and economically can. Under good operating conditions solvent extraction will reduce the oil level of the residue to under one percent. To try to recover a significant part of the remaining one percent is uneconomic.

For food use purposes of the protein residue, solvent extraction offers a distinct advantage in versatility. Commonly, for feed use the solvent is removed from the defatted residue in a desolventizer toaster. Under properly controlled conditions this will minimize anti-nutritional factors and maximize the feed quality of the proteins. However, it also denatures the proteins to the extent that their solubility is substantially reduced. For the preparation of isolates and some food uses this low protein solubility is a disadvantage. However, desolventizers have been designed and are in use that can be operated under conditions to retain all or a part of the protein solubility. It is, therefore, common for a food manufacturer to purchase food grade soybean meal or flour with a specified nitrogen solubility based upon his product development experimentation. In some food systems a high nitrogen solubility is desirable, in others an intermediate, and in some a low nitrogen solubility is preferred.

The pre-press solvent extraction process does not have as much flexibility as does the direct solvent extraction. There is enough frictional heat developed in the pre-pressing to effect a substantial reduction in nitrogen solubility. This is the case in ordinary commercial practice. It is possible to operate the prepress section in such a way as to minimize the loss in nitrogen solubility and still produce a press-cake suitable for solvent extraction. Under these conditions less oil is removed in the pre-press operation and, consequently, there will be need for a higher solvent to meats ratio in the extraction. To minimize the nitrogen solubility loss requires very careful control of the pre-press operation.

PROCESSES FOR OILSEED PROTEIN CONCENTRATES

The presently available soy protein concentrates result from the removal of most of the oil and the water soluble constituents of de-hulled soybeans (Figure 2). In most seasons the concentrates will contain about 70% protein (N x 6.25). While this has rather inadvertently become the accepted standard and definition of soy concentrates and is being somewhat improperly applied to concentrates from other oil-seed sources, the initial objective of the process was to eliminate those components responsible for much of the flavor and odor of soy-beans. Coincidentally, the flatus producing components are also greatly reduced or eliminated.

There are at least three processes in commercial use for making soy protein concentrates. These differ in the technology employed to render the major proportion of the protein insoluble during the extraction step.

1. Extraction with 60 to 80% aqueous ethanol.[9]
2. Insolubilize the protein with heat and then extract with water[10]
3. Aqueous extraction at the isoelectric pH (point of lowest solubility) of the major protein components.[11, 12]

The products of the first two processes are denatured and, consequently, insoluble. The isoelectric process may suffer a somewhat larger loss of protein in the whey, but yields a much more soluble protein concentrate. In the isoelectric process it is common to neutralize the concentrate prior to drying.

A similar concentrate can be made from cottonseed flour[13] and probably from other oilseed flours. The solubles contain sugars, minerals and some nitrogenous constituents, some of which is protein. These constitute a significant loss of the original components and a potential pollution hazard. Work is in progress at Texas A&M University to identify the components of an oilseed whey, develop methods for the recovery of the major components and find economic uses for them. It has already been demonstrated that cottonseed whey contains a component or components that have good whipping properties.[14]

As has been mentioned previously, a liquid cyclone process has been developed for the removal of pigment glands as measured by gossypol from the present varieties of cottonseed.[15, 16] Figure 3 shows the basic elements of the process. The classification is carried out in a liquid-solid cyclone which separates solid particles on the basis of their size and specific gravity. The pigment glands, which are tough and resilient enough to resist disruption during hexane extraction and grinding to a slurry, flow in a direction opposite to the major portion of the protein. The major product represents 65% of the initial protein and slightly more than half of the defatted cottonseed meal. The protein content of the major fraction is at least 65% and the gossypol is reduced to less than 0.1%. This type of product is presently being marketed in India under the trade name "Stamiro" and is expected to be available in the United States in early 1973.

It is a resonable presumption that the liquid cyclone could also be used to concentrate the protein in glandless cottonseed meal.

A protein concentrate can also be produced from properly ground, defatted cottonseed meal by air classification[16, 17] (Figure 4). With glanded meal this process is less effective than liquid classification in reducing the gossypol level. However, because of the simplicity of the process it could find considerable application with glandless meal and perhaps with other defatted oilseed meals.

PROCESSES FOR OILSEED PROTEIN ISOLATES[8, 18, 19]

Although food grade protein isolates have been produced from soybean flour for over ten years, there is little published information on the details of the design, equipment and operating conditions used in the processing plants. The general procedure for the preparation of soybean protein isolates is shown in Figure [illegible]. It is important that the defatted soy flakes or flour used as a starting material have been treated as mildly as possible to minimize denaturation and retain maximum protein solubility. In the alkaline extraction the parameters of pH, time, temperature and liquid-solids ratio are undoubtedly controlled for optimized throughput and economics. The extract may be separated from the insoluble materials by a filter or a centrifuge. The pH of the extract is then adjusted to the point of minimum solubility of the proteins, approximately 4.5, and the precipitated proteins are separated, washed with water, and separated again by filteration or centrifugation.

The precipitated protein which is still at or near its isoelectric point may be dried, most commonly by a spray dryer. Most soy protein isolate is neutralized to sodium proteinate prior to drying as this greatly enhances its dispersibility in water. The yield of protein isolates from defatted soy flakes is from 30 to 40%. The protein content (N x 6.25) is generally in excess of 90%.

Note that in the process there are two by-products: (1) a residue insoluble in alkali, and (2) the materials that are soluble at the isoelectric pH. The latter, being a rather dilute solution, represents a significant problem of disposal.

Similar approaches have been made to the preparation of protein isolates from other oilseed sources. Because the oilseeds and their proteins differ, the most appropriate isolation procedure for each will differ. For example, with cottonseed a two-step procedure has been developed which yields two distinct and different protein isolates[20] (Figure 6). The first isolate is obtained by extraction with water and precipitation at pH 4. About one-fourth of the total protein is extracted and about 15% recovered as the first isolate.

The insolubles from the water extraction are then extracted with 0.015 NaOH (pH about 9.7) and precipitated by acidification to pH 7. This extracts about 60% of the original protein and the second isolate represents slightly more than half of the protein originally present in the cottonseed meal. The two isolates constitute about 10 and 30% of the initial total weight of the meal. A modification of this process in which all of the cottonseed protein is extracted in an alkaline medium and then selectively precipitated has also been recently reported.[21] The wheys resulting from the preparation of protein isolates are presumed to be similar to those from the production of concentrates. Therefore, the research mentioned above into the utility of the compoents of wheys is considered to be applicable both to those from the isolate and from the concentrate processes.

AN AQUEOUS CENTRIFUGAL PROCESS FOR THE RECOVERY OF OIL & PROTEIN PRODUCTS FROM OILSEEDS

As pointed out above, currently available processes for the recovery of oil from high-oil oilseeds commonly result in sufficient denaturation of the proteins to lower their solubility and restrict their range of utility in food products. In addition, a pre-press solvent extraction plant is both hazardous and expensive, especially if equipment is added to convert the oilseed flour into concentrates and isolates. Because of this alternative processes have been sought for the recovery of oil and food grade protein products from oilseeds. Principle attention has been focused on the use of aqueous centrifugal processes and substantial numbers of investigations have been reported and reviewed.[22] Two of the leading research centers that have been active in this area have been the Central Food Technological Research Institute in Mysore, India[23] and the Tropical Products Institute in England.[24] It is reported that the Tata Oil Mills in Bombay, India[25] are using a modification of the CFTRI process for the manufacture of peanut protein isolates. For the past three years, the Food Protein Research & Development Center at Texas A&M University has been diligently investigating these processes. On the basis of laboratory investigations and pilot-scale unit operations it is now believed that the aqueous centrifugal processing of both coconuts[26] and peanuts[27] is practical and can yield high quality oils and food grade protein products at competitive costs.

Figure 7 shows a simplified flow diagram of the aqueous processing of coconuts. Because the process starts with fresh, husked coconuts and is continuous, the oil has a minimum opportunity to hydrolyze and consequently, has a low free fatty acid and good color. In discontinuous unit operations, such as in a pilot plant, it is difficult to obtain realistic material balance data because there is so much product loss by adherence to the many pieces of equipment and in the necessary mass transfers. Nonetheless, recoveries of oil in the oil product in the range of 93% have been obtained. It is believed that in a continuous commercial plant the oil recovery probably would exceed 95%.

Presently the protein fraction of principle interest is that referred to as Coconut Fraction S. Its composition is approximately 25% protein 5% fat, 45% soluble carbohydrates and 9% ash. This composition is not too dissimilar from that of non-fat dry milk. The soluble carbohydrate is principally sucrose. The flavor of the product is sweet and mildly coconut. Because of its high level of solubility it is believed that it can be used in many of the applications of non-fat dry milk and particularly as a beverage base. If one assumes only a 90% recovery of oil in the process and assigns no value to the Fibrous Residue or Protein Concentrate I, it is estimated that the Coconut Fraction S would cost 16¢ per pound to produce. The real cost should be substantially less than this inasmuch as it is fully anticipated that a higher than 90% recovery of oil will be obtained and that both the Fibrous Residue and Protein Concentrate I will be shown to have real value.

Earlier attempts have concentrated on the production of an isolate as shown in the alternate process in Figure 7. Because the oil clings rather tenuously to the protein the acid precipitated fraction contains about 65% protein, 24% oil, 2% ash and 3.5% soluble carbohydrates. Because the yield is so low the cost to produce the acid precipitated fraction would be about 59¢ per pound, if it were assumed to be the only marketable product. Even presuming that the cost can be reduced by improving the oil recovery and finding markets for the other by-products, it is probable that the cost of the acid precipitated protein will be sufficiently high that its marketability will depend upon finding some unusually useful application.

The above costs were calculated on the basis of a hypothetical processing plant which would handle 125 metric tons per day of husked coconuts. Processing costs were estimated at $15.80 per ton of husked coconuts processed. The estimated total equipment cost is $650,000. The total installed plant cost would depend upon the location of the plant and the labor rates prevailing in that area.

With peanuts an aqueous centrifugal·oil mill can be designed and operated to yield either a concentrate (Figure 8) or an isolate (Figure 9). A concentrate can generally be used for the same purposes as an isolate and often at lower cost. This is true in the case of the aqueous processing of peanuts inasmuch as both oil and protein yields are higher in the concentrate process than in the isolate process. Material balance data obtained in a discontinuous pilot plant indicate that about 92% of the protein and 89% of the oil present in the peanuts can be recovered by the concentrate process shown in Figure 8. Again, it is anticipated that these yields would be improved in a continuously operated commercial plant. The final peanut protein concentrate contains about 67% protein and 9% oil. Based on the above recoveries, it is estimated that this concentrate would cost about 15¢ per pound (23¢ per pound of protein). While the properties of this concentrate have not been exhaustively explored at this time, it does exhibit a very high level of solubility in water in the neutral pH range and a moderately low viscosity.

An advantage of the aqueous processing of peanuts is that this provides a suitable medium for the chemical attack on aflatoxin. Most chemicals that have proven to be effective in the destroying of aflatoxin are most effective in an aqueous system. This is the present thrust of investigations at Texas A&M University in the aqueous processing of peanuts.

FIBROUS PRODUCTS

There are two classes of fibrous products that are currently being produced from soybean products. The first of these is based on spun fibers and the second on extruded flours.

In the production of the spun fiber products, as shown in Figure 10, isolated soy protein is dissolved at 10 to 20% solids in an aqueous alkaline solution with a pH of 10 or above. This provides the spinning "dope" which is forced through a standard, noble metal "spinnerette" and emerges into a coagulating bath adjusted to the isoelectric pH of the protein. Here precipitation occurs.

If this precipitate is drawn away continuously from the discharge face, the monofilaments may be produced endlessly so long as the alkaline dispersion is supplied under pressure and the coagulating bath chemicals are replenished. The isoelectric bath is an aqueous solution of a food grade acid and often contains dissolved electrolytes. For example, for soy isolate, acetic acid and sodium chloride are used.

The choice of the size of the spinnerette orifice is important to the ultimate texture of the products. Generally a diameter of under 0.008 inches is used. The tenderness and toughness of the fibers can be influenced by stretching and heat setting the stretched material. The texture of finished foods can be varied by altering the geometric arrangement of the filaments over a range from essentially parallel to nearly random. This is effected during the compounding of the food product. Finished textured foods usually contain about 35 to 65% of their dry weight as spun protein fibers. These are compounded with fats, flavors, coloring agents, nutrients, thermo-setting binding agents and so forth to fabricate simulated meat products.

A more recent class of fibrous, textured products is made by the extrusion of soy flour or flakes. The soy flour at a suitable moisture level is put through an extrusion device wherein the temperature and pressure at the orifice cause an elongation of the protein into a fibrous structure. After exiting from the extruder, the elongated fibrous structure maintains its integrity when the product is used in ordinary cookery. The dried products will absorb up to 3 times their weight of moisture and exhibit many of the physical properties of chunks of meat.

Coloring and flavoring agents may be added to the fibrous products. The openness of the texture and the rate of rehydration appear to be related to the operating characteristics of the extrusion equipment used.

SOY MILK[28]

Soy milk has been produced for a long time by a rather wide assortment of processes. The process employed generally depends upon the availability of equipment and the quality characteristics desired. A typical process is shown in Figure 11. In some instances the cleaned soybeans may be soaked in water one or more times. The soak water may be discarded. The beans are then disintegrated in water by a variety of grinding and pulverizing devices. Research at Cornell University has shown that the use of water heated to at least 80°C in the disintegration step will prevent lipoxidase activity and result in better flavors.

The disintegrated slurry must be heated at some point in the process sufficiently to destroy the trypsin inhibitor activity in the soybeans. In those cases where the end product is a bottled beverage this heating is probably part of the final sterilization operation.

The slurry may be filtered or centrifuged to remove the least soluble and dispersible components that would settle out in a beverage or produce an unpleasant, gritty feel in the mouth. Depending upon the degree of separation of insolubles, the yields of solids in soy milk will range from about 65 to 90% of the original dehulled soybeans.

COMPARATIVE FOOD USE POTENTIAL OF THE PROTEIN PRODUCTS THAT CAN BE DERIVED FROM OILSEEDS

The food use potential of any new product or class of products depends upon how they fit into traditional food patterns and food economics. A product that is a big success in one place may have no potential for success in another. Consequently, it is hazardous to make projections from the experiences to date which have been mostly in the United States, to the potential for oilseed proteins in other countries.

There is an old adage that "necessity is the mother of invention." Certainly in this case the tremendous need to expand our food protein supplies is going to stimulate an upsurge in creativity. Further, most countries would prefer to use indigenous products. Presently, most of the commercial technology is based upon soybeans. Undoubtedly, an increasing amount of attention will be directed toward other oilseeds.

It is possible to anticipate general trends that will develop in the utilization of oilseed proteins. Certainly the area of meat extenders and alternates will come in for much attention. Except where it is precluded for religious reasons, meat is generally one of the most preferred foodstuffs. Its consumption is restricted only by income. Tremendous progress has already been made in developing meat extenders and alternates from soy products. Those made from the spun fibers have proven to be very versatile and to have high consumer acceptability. However, their cost will be a deterrent. The extruded products, however, are inexpensive and have a wide range of potential uses. All of the present technology is based on extruded soy flour and it is not known whether acceptable counterparts can be produced from the other oilseeds.

Another area of substantial interest is beverages. This interest has two facets, that of producing extenders or replacers for milk and that of fortifying with protein the many beverages that are consumed strictly for pleasure, principally carbonated. In both cases flavor is a controlling criterion. While the success of Vitasoy in Hong Kong has attracted much attention, the flavor of Vitasoy is certainly not universally accepted. A soy milk like Vitasoy has a strong characteristic flavor that many people consider unpleasant. Therefore, there has been considerable effort to modify the flavor of soy beverages. There has been some success in doing this in blends with cheese whey with properly controlled processing to overcome the soy flavor. Soy has the additional disadvantage that it produces a rather substantial increase in viscosity with a small increase in concentration. Peanut protein, on the other hand, is considerably more soluble than that of soy and produces a much lower increase in viscosity. While these oilseed proteins can be used in conjunction with whey or other milk products, a different problem is encountered if one attempts to make a simulated milk without the inclusion of a dairy product. It is presumed that a synthetic milk should have a protein and mineral content similar to that of natural milk. It is a characteristic of several of the vegetable proteins that while they may be soluble in water at the pH of milk, they precipitate in the presence of low levels of calcium ions. This is an area where much new research is needed.

In the case of the carbonated (acid) beverages one must look for a protein that is soluble at a low pH. The major isolate from cottonseed has this property. In addition, the whey proteins from oilseed processing are also soluble at low pH's.

It is suggested that the water soluble fraction from coconut processing could be converted into a beverage that might be positioned between milk and the pleasure beverages. It has a composition very close to that of milk powder, but with its sweet coconut flavor might be marketable on its merits as a pleasure beverage. There has not yet been enough produced to make any consumer tests.

A third potential area is in the protein fortification of bread and other bakery items. In the case of the unleavened bakery products flavor and color are undoubtedly the controlling criteria. In these applications probably all of the oilseed proteins that have been rendered essentially flavorless and colorless should find utility. It must be recognized, however, that in general even the lowest cost oilseed protein concentrates, that is the flours, will probably be more expensive than the ingredients they replace. The added cost would have to be borne by the product and would make its marketing more difficult. While the nutritional benefit of the added oilseed flour could be a real bargain, in a direct price competition with an unfortified product the marketing appeal would have to be based upon nutrition which in the past has not been a very effective sales tool.

In the case of leavened baked goods even the strongest wheat flour is adversely affected by relatively small additions of oilseed flours. The Kansas State group has shown that the use of commercially available dough conditioners, especially sodium stearoyl lactylate, assists in making wheat flour more tolerant of the oilseed flours, particularly soybean flour.[29] Work at Texas A&M University has shown that the oilseed flours vary in their incompatibility with wheat flour and that peanut flour and sesame flour especially are much better tolerated.[30] The objective of this latter research is ultimately to learn why the oilseed proteins differ and using that knowledge hopefully to develop techniques for making any oilseed flour compatible with wheat flour.

There is and will continue to be activity in a number of other food product development areas, including infant foods, weaning foods, geriatric foods, snack items, fat control diets, cholesterol control diets, etc. Each of these has its own product criteria and consequent raw material demands. While all of the oilseed proteins should participate in this development effort, essentially of the work that has been done to date has been based on products derived from soybeans.

CONCLUDING REMARKS

Applications research into the utilization of oilseed proteins in a wide variety of food products is moving at a pace so rapid and so widespread that it is almost impossible to comprehend. The great preponderance of progress is being made in the food industries in developed countries with profit as the primary motive. Because of the ready availability of raw materials upon which to do development work, all of the effort has been concentrated upon products derived from soybeans. Consequently, the spin-off benefit to most of the developing countries is limited. This presumes that most of the developing countries would prefer to use indigenous raw materials and in most of those that raw material is an oilseed other than soybeans.

While it is easier to follow the lead of the big food companies in the developed countries and take advantage of the rapidly increasing knowledge about the properties of soy protein products, it would seem that the better, long range strategy for the developing countries would be to concentrate their efforts upon the oilseeds they can best produce in their own countries. LCP flour from glanded cottonseed is the first generation non-soy product that is and will be avaiable in substantial quantities. Its potential should be investigated extensively. The techniques for converting all the world's cotton production to glandless are now available. Techniques are being developed for the recovery of food grade protein products from peanuts and coconuts. Substantial progress is being made with rapeseed. The developing countries do not have to depend upon soybean as a source of food protein, but to avoid that dependence it will be necessary to increase the rate of development of techniques for the recovery and utilization of the proteins in the oilseeds indigenous to those countries

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TABLE 1

WORLD PRODUCTION OF OILSEED PROTEINS-1971(1)

	World Production of Oilseeds (million metric tons)	Estimated Protein Content (%)(2)	Estimated World Production of Oilseed Proteins (million kg)
Soybeans	43.6	40	17,450
Cottonseed	22.5	21	4,730
Peanuts	18.1	19	3,450
Sunflower Seed	9.4	19	1,780
Rapeseed	7.7	20	1,540
Flaxseed	2.8	25	690
Sesame Seed	1.9	25	450
Coconut Oil	2.4	12	290

(1) From USDA Foreign Agricultural Service, Foreign Agricultural Circular, Washington, D. C., February 1972.

(2) Table 1 World Production of Oilseed Proteins 1969, Amino Acid Fortification of Protein Foods, edited by Nevin S. Scrimshaw and Aaron M. Altschul, p. 128, The MIT Press, Cambridge, Mass., 1969.

(3) Data for coconut oil believed to be more reliable than production data for coconuts or copra.

TABLE 2

ESTIMATED WORLD PRODUCTION OF OILSEEDS
(million metric tons)

	Average 1960-64 (1)	1966 (1)	1967 (1)	1968 (1)	1969 (1)	1971 (2)	% Change 1960-64 to 1971
Soybeans	27.6	34.8	36.6	39.8	40.6	43.6	+57.9
Cottonseed	20.4	20.3	20.4	22.4	21.9	22.5	+10.3
Peanuts	14.8	16.2	17.2	14.8	16.7	18.1	+22.2
Sunflower Seed	6.6	8.6	9.4	9.3	9.2	9.4	+42.4
Rapeseed	3.6	4.4	5.0	5.4	5.2	7.7	+113.9
Flaxseed	3.3	3.0	2.3	3.1	3.6	2.8	-15.1
Sesame Seed	1.5	1.5	1.6	1.5	1.6	1.9	+26.6
Coconut Oil	2.1	2.3	2.1	2.1	2.0	2.4	+14.2

(1) Table 2, Estimated World Production of Oilseeds (million metric tons), Amino Acid Fortification of Protein Foods, edited by Nevin S. Scrimshaw and Aaron M. Altschul, p. 128, The MIT Press, Cambridge, Mass., 1969.

(2) From USDA Foreign Agricultural Service, Foreign Agricultural Circular, Washington, D. C., February 1972.

TABLE 3 SOYBEANS: PRODUCTION IN MAJOR PRODUCING COUNTRIES AND ESTIMATED WORLD TOTALS (1,000 metric tons)(2)

	1968	1969	1970	1971	Yield Per Acre (in kilograms) 1971
UNITED STATES	30,022	30,653	30,911	31,990	.750
CHINA (MAINLAND)	6,480	6,200	6,900	6,900	.350
BRAZIL	654	1,057	1,332	3,100	.680
U.S.S.R.	528	434	629	--	--
INDONESIA	420	389	488	391	.230
MEXICO	270	300	240	150	.810
SOUTH KOREA	245	229	232	246(1)	.320(1)
CANADA	246	209	283	256	.710
JAPAN	168	136	126	125	.504
ESTIMATED TOTAL	39,643	40,361	41,959	43,687	

(1) From USDA Foreign Agricultural Service, Foreign Agricultural Circular, Washington, D.C., October 1971.

(2) Ibid., March 1972.

TABLE 4 COTTONSEED: PRODUCTION IN MAJOR PRODUCING COUNTRIES (1)
(1,000 metric tons)

	1966	1967	1968	1969	1970	1971
UNITED STATES	3,592	2,912	4,209	3,690	3,713	4,031
U.S.S.R.	3,755	3,755	3,755	3,600	4,365	3,960
CHINA (MAINLAND)	2,750	2,960	2,875	2,875	2,915	2,915
INDIA	2,008	2,312	2,138	2,225	1,963	2,095
BRAZIL	905	1,193	1,458	1,370	994	1,281
PAKISTAN	928	1,056	1,073	1,093	1,071	1,171
U.A.R.	820	758	758	921	884	910
TURKEY	611	634	696	640	640	750
MEXICO	980	871	1,067	762	627	679
SUDAN	343	334	426	442	453	455
IRAN	230	233	305	314	305	288
SYRIA	288	256	311	303	303	265
COLUMBIA	177	205	283	260	239	256
ARGENTINA	177	148	228	294	177	254
GREECE	187	204	155	236	234	249
PERU	200	197	180	165	167	169
UGANDA	154	126	154	172	154	168
NICARAGUA	243	206	188	143	160	161
TANZANIA	159	142	103	143	128	161
GUATEMALA	122	148	142	102	105	110
SPAIN	181	132	154	117	106	88

(1) From USDA Agricultural Research Service Statistical Report, World Agriculture Production and Trade, October 1971

TABLE 5 PEANUTS: PRODUCTION IN MAJOR PRODUCING COUNTRIES (1,000 metric tons)(1)

	1968	1969	1970	1971
INDIA	4,631	5,130	6,065	5,800
CHINA (MAINLAND)	2,150	2,350	2,650	2,700
NIGERIA	1,445	1,360	780	1,100
UNITED STATES	1,153	1,147	1,351	1,357
SENEGAL	830	800	554	800
BRAZIL	754	754	810	800
INDONESIA	410	382	419	475
BURMA	398	444	421	--
SUDAN	164	382	353	--
NIGER	252	280	236	240
SOUTH AFRICA	224	343	303	380
CHAD	110	115	115	--
CONGO	17	20	20	--
MALI	96	120	100	--
MOZAMBIQUE	109	119	--	--
MALAWI	130	212	153	--
ZAMBIA	47	62	42	103
UGANDA	234	234	234	--
TAIWAN	106	101	122	--
JAPAN	122	126	124	125
THAILAND	158	180	220	--

(1) From USDA Foreign Agricultural Service, Foreign Agricultural Circular, Washington, D. C., November 1971.

TABLE 6 SUNFLOWER SEED: PRODUCTION BY MAJOR PRODUCING COUNTRIES (1) (1,000 metric tons)

	1965	1966	1967	1968	1969	1970	1971
U.S.S.R.	5,013	5,638	6,079	6,150	5,849	5,652	5,244
Romania	564	671	720	730	747	769	900
Argentina	757	782	1,120	940	876	1,140	830
Bulgaria	357	423	478	456	541	407	450
Turkey	160	200	230	230	310	375	400
Yugoslavia	265	282	250	309	390	264	347
Spain	9	33	21	31	153	160	254
United States	17	30	102	71	78	85	162
Hungary	75	102	79	94	114	92	150
South Africa	74	102	101	82	90	97	128
Australia	2	3	2	3	6	13	84
France	18	21	19	26	30	49	74
Canada	13	15	16	11	15	25	69
Uruguay	39	99	76	49	63	65	48
Chile	47	54	33	43	28	20	29

(1) USDA Foreign Agricultural Service, Foreign Agricultural Circular, Washington, D. C., February 1972.

TABLE 7

RAPESEED: PRODUCTION IN MAJOR PRODUCING COUNTRIES (1,000 metric tons) [1]

	1968	1969	1970	1971
INDIA	1,568	1,347	1,564	1,963
CHINA (MAINLAND)	786	688	780	830
POLAND	712	204	566	450
PAKISTAN	396	358	378	375
CANADA	440	758	1,638	2,234
FRANCE	457	513	567	621
EAST GERMANY	265	164	180	210
SWEDEN	263	208	183	215
WEST GERMANY	170	158	185	224

(1) From USDA Foreign Agricultural Service, *Foreign Agricultural Circular*, Washington, D. C., December 1971.

TABLE 8

COMPOSITION OF OILSEEDS

	Protein %	Oil %	Crude Fiber %	Ash %
Soybean[5]	42	20	5.0	--
Cottonseed	21[5]	19[5]	10[5]	4.4
Peanuts[a]	19[1]	48[2]	2.8-3.0[3]	2.5-3.0[3]
Sunflower Seed	13.6[5]	39.6[5]	14.4[5]	3.5[3]
Rapeseed[4]	20	51	3.8	3.5
Sesame Seed	25[1]	50[2]	4[3]	5[3]
Coconut[6]	7.4	69	4.9	1.8

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(a) Decorticated.

TABLE 9

COMPOSITION OF OILSEED MEALS

	Protein %	Oil %	Crude Fiber %	Ash %
Soybean(1)	45.8	0.9	6.0	5.8
Cottonseed(1)	41.6	1.6	11.0	6.5
Peanuts(2)	49-57	0.6-3.0	4.0-5.7	4.9-6.0
Sunflower Seed(1)	46.8	2.9	11.0	7.7
Rapeseed(2)	36.9	3.1	9.3	7.3
Sesame Seed(3)	60-80(3a)	0.6-1.6	2.7-3.7	10.5-13.2
Coconut(4)	24.0	0.5	7.8	5.5

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(3a) Protein = N x 6.25.

(4) Development of a Process for Preparation of Coconut Protein Products for Use in Foods," Seventh Quarterly Report, Food Protein Research & Development Center, Texas A&M University, Table 17, April 1972.

TABLE 10

AMINO ACID CONTENT OF OILSEEDS[1]

	Soybean	Cottonseed	Groundnut	Sunflower Seed	Rapeseed[2]	Linseed	Coconut	Sesame Seed
Nitrogen (g/100g)	6.65	3.81	4.69	2.38	3.8	3.40	1.25	3.42
Conversion Factor (N)	5.71	5.30	5.46	5.30	5.23	5.30	5.30	5.30
Protein (g/100g)	38.0	20.2	25.6	12.6	20.0	18.0	6.6	18.1
Protein/Calorie (%)	39.4	16.0	16.3	19.8	----	12.5	3.9	10.9
Amino Acids mg/gN								
Isoleucine	284	206	211	269	242	271	244	226
Leucine	486	370	400	401	428	382	419	[illegible]
Lysine	399	276	221	225	326	237	220	171
Methionine	79	81	72	119	113	122	120	174
Cystine	83	97	78	93	183	120	76	[illegible]
(Total-Sulfur Containing)	162	178	150	212	296	242	146	[illegible]
Phenylalanine	309	326	311	273	241	299	283	[illegible]
Tyrosine	196	180	244	118	184	170	167	[illegible]
(Total Aromatic)	505	506	555	396	425	469	450	[illegible]
Threonine	241	206	163	230	267	239	212	[illegible]
Tryptophane	80	78	65	85	74	97	58	84
Valine	300	290	261	317	310	339	537	288
Arginine	452	700	697	499	320	598	922	[illegible]
Histidine	158	170	148	145	145	150	128	[illegible]
Alanine	266	254	243	263	260	308	279	[illegible]
Aspartic Acid	731	536	712	579	414	556	553	[illegible]
Glutamic Acid	1169	1249	1141	1365	1080	1207	1171	1213
Glycine	261	264	349	338	295	366	281	305
Proline	343	236	272	279	456	239	223	231
Serine	320	277	299	270	285	310	303	291
Total Essential	2457	2110	2026	2133	2368	2276	2149	2172
Total Amino Acids	6157	5846	5887	5871	5621	6000	5918	5916
Limiting Amino Acids	Sulfur-Containing	Isoleucine	Sulfur-Containing	Lysine	Isoleucine Methionine	Lysine	Lysine	Lysine

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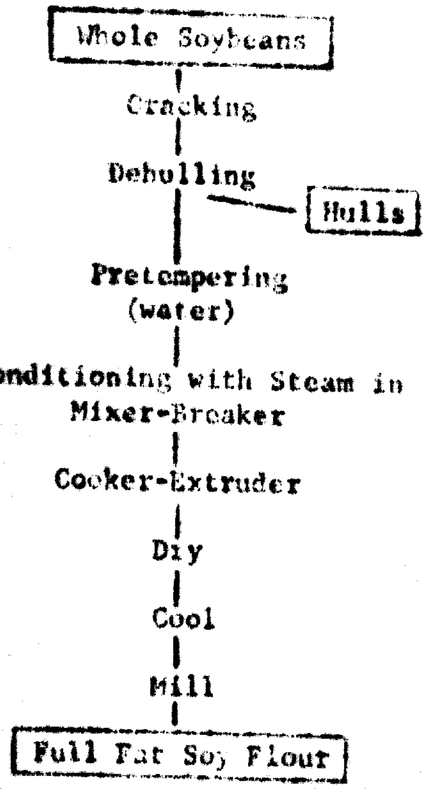
(1) Amino Acid Content of Foods and Biological Data on Proteins, Food Policy and Food Science Service, Nutrition Division, Food and Agriculture Organization of the United Nations, 1970.

(2) Eklund, A., Agren, G., Langler, F., Strenram, U. and Nordgren, Rapeseed Protein Fractions II - Chemical Composition and Biological Quality of a Lipid-Protein Concentrate from Rapeseed (*Brassica napus* L.), J. Sci. Food & Agri., 22(12):653-657, 1971.

FIGURE 1

PRODUCTION OF FULL FAT SOY FLOUR



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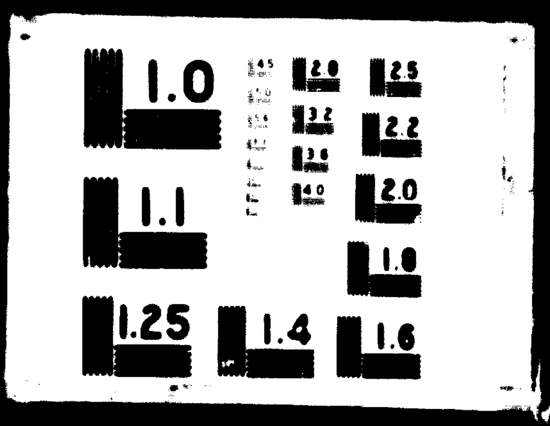


FIGURE 2

PRODUCTION OF SOY PROTEIN CONCENTRATES

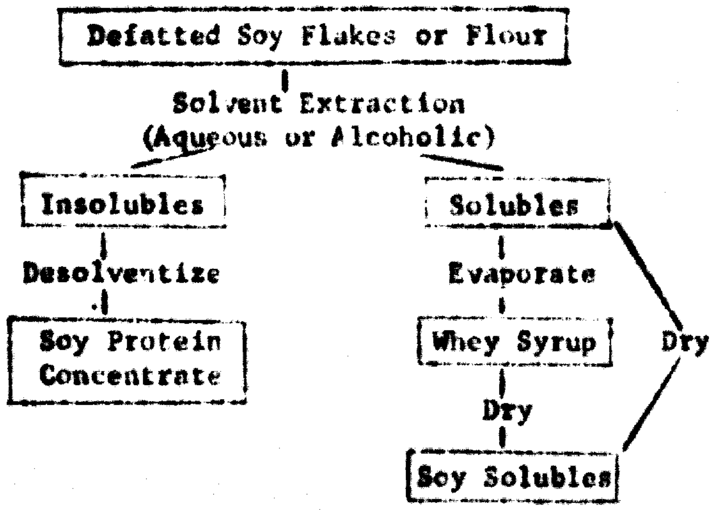


FIGURE 3

PRODUCTION OF PROTEIN CONCENTRATE FROM COTTONSEED BY LIQUID CLASSIFICATION

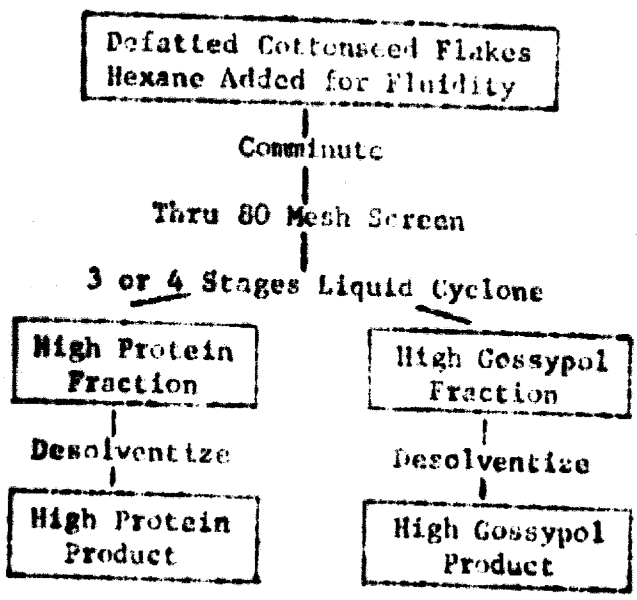


FIGURE 4

PRODUCTION OF PROTEIN CONCENTRATE FROM COTTONSEED BY AIR CLASSIFICATION

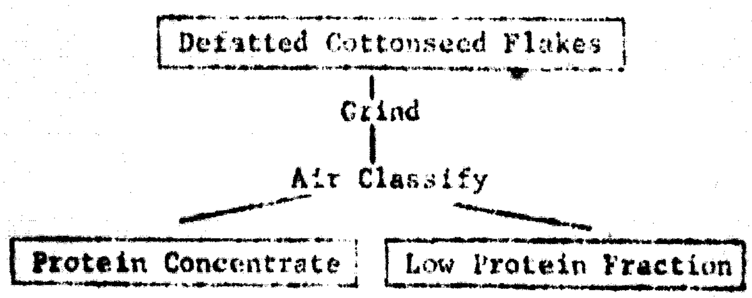


FIGURE 5

PRODUCTION OF SOY PROTEIN ISOLATE

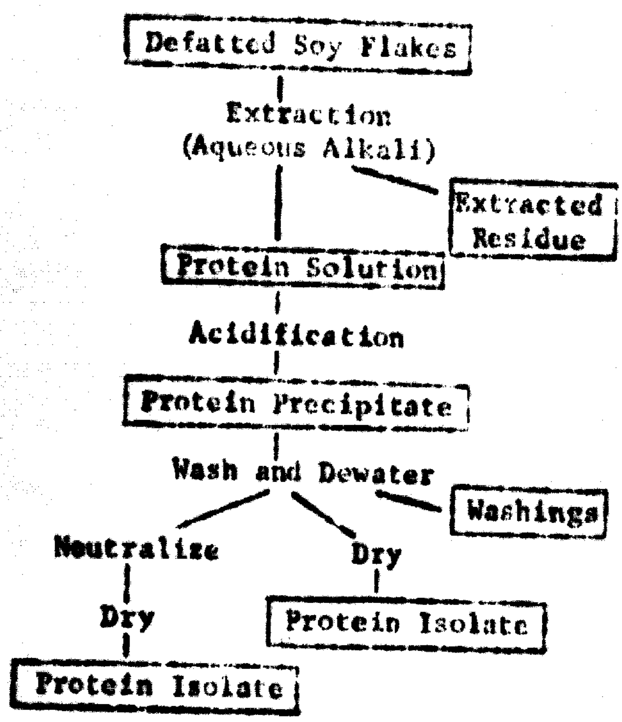
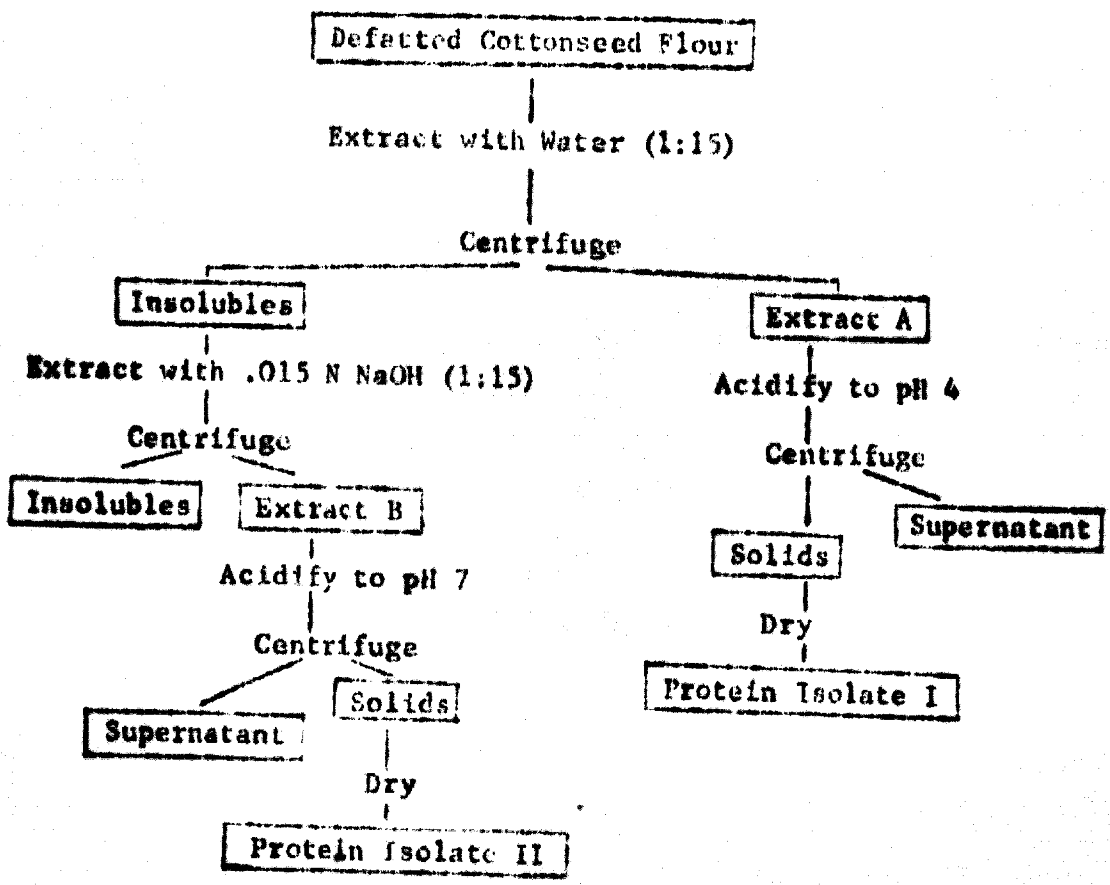


FIGURE 6

TWO STEP PRODUCTION OF
COTTONSEED PROTEIN ISOLATES



SIMPLIFIED FLOW DIAGRAM FOR THE AQUEOUS PROCESSING OF COCONUTS WITH COCONUT WATER

FIGURE 7

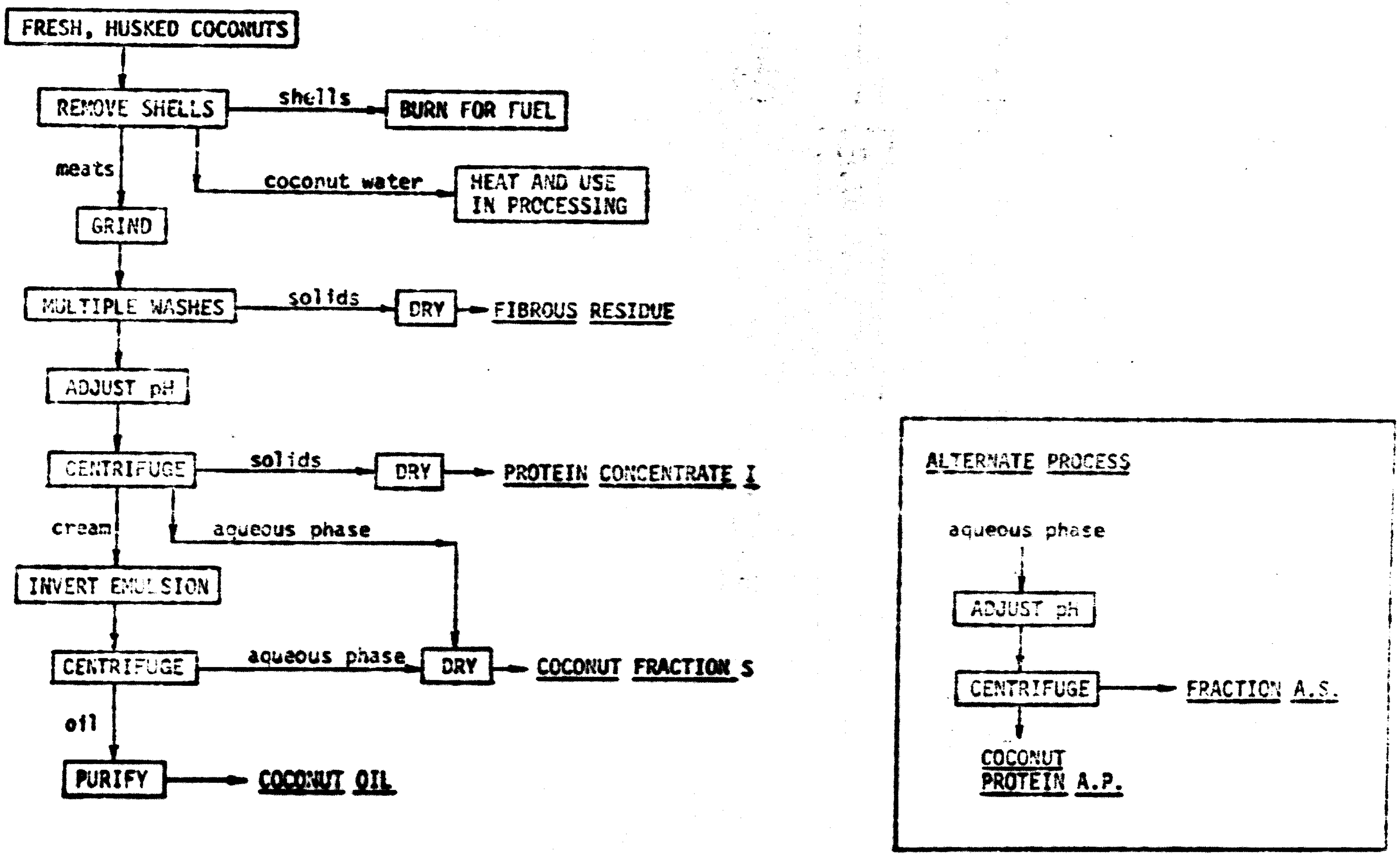


FIGURE 8

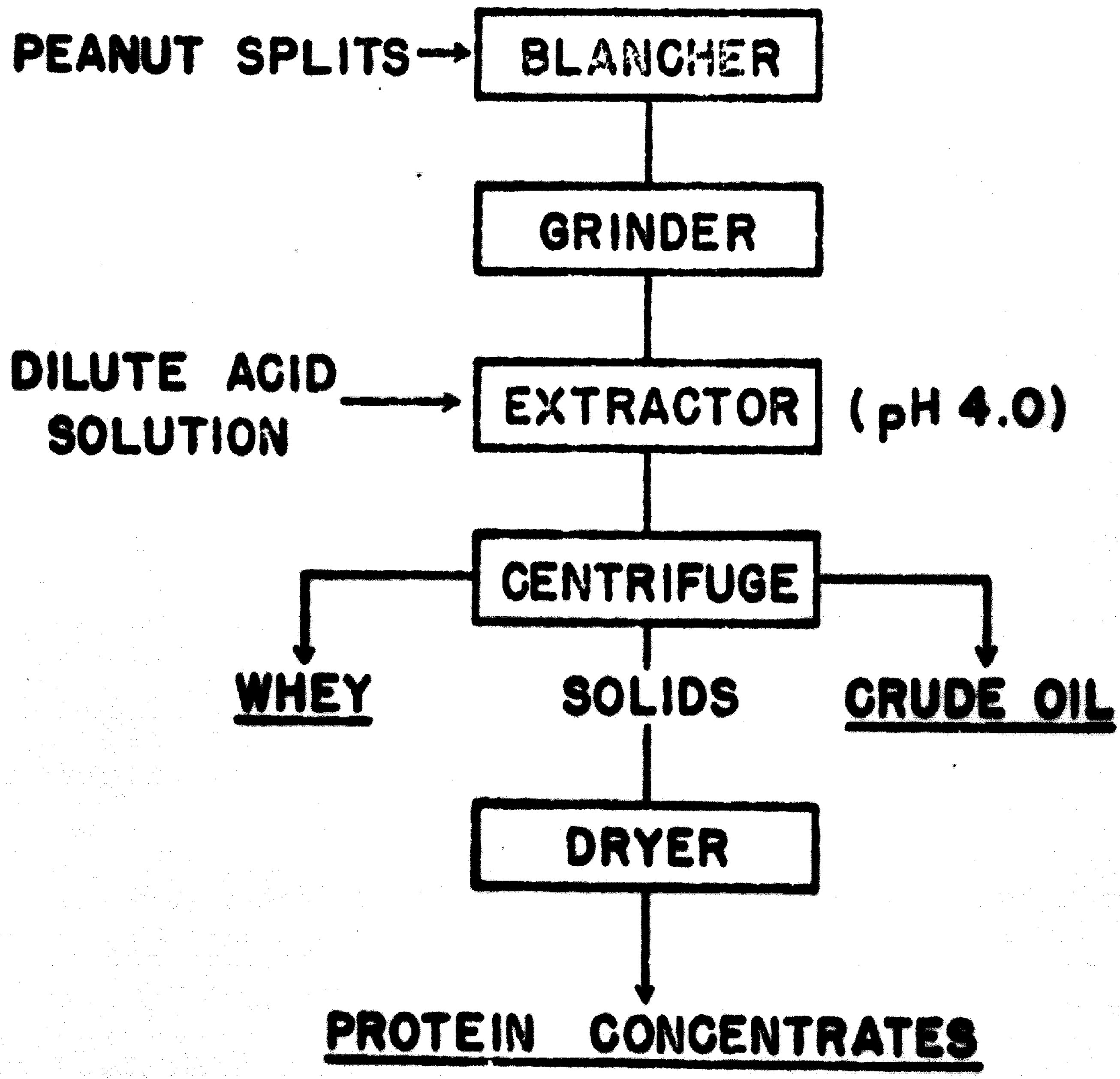

PEANUT SPLITS
BLANCHER
GRINDER
DILUTE ACID SOLUTION
EXTRACTOR
(pH 4.0)
CENTRIFUGE
WHEY
SOLIDS
CRUDE OIL
DRYER
PROTEIN CONCENTRATES

FIGURE 9

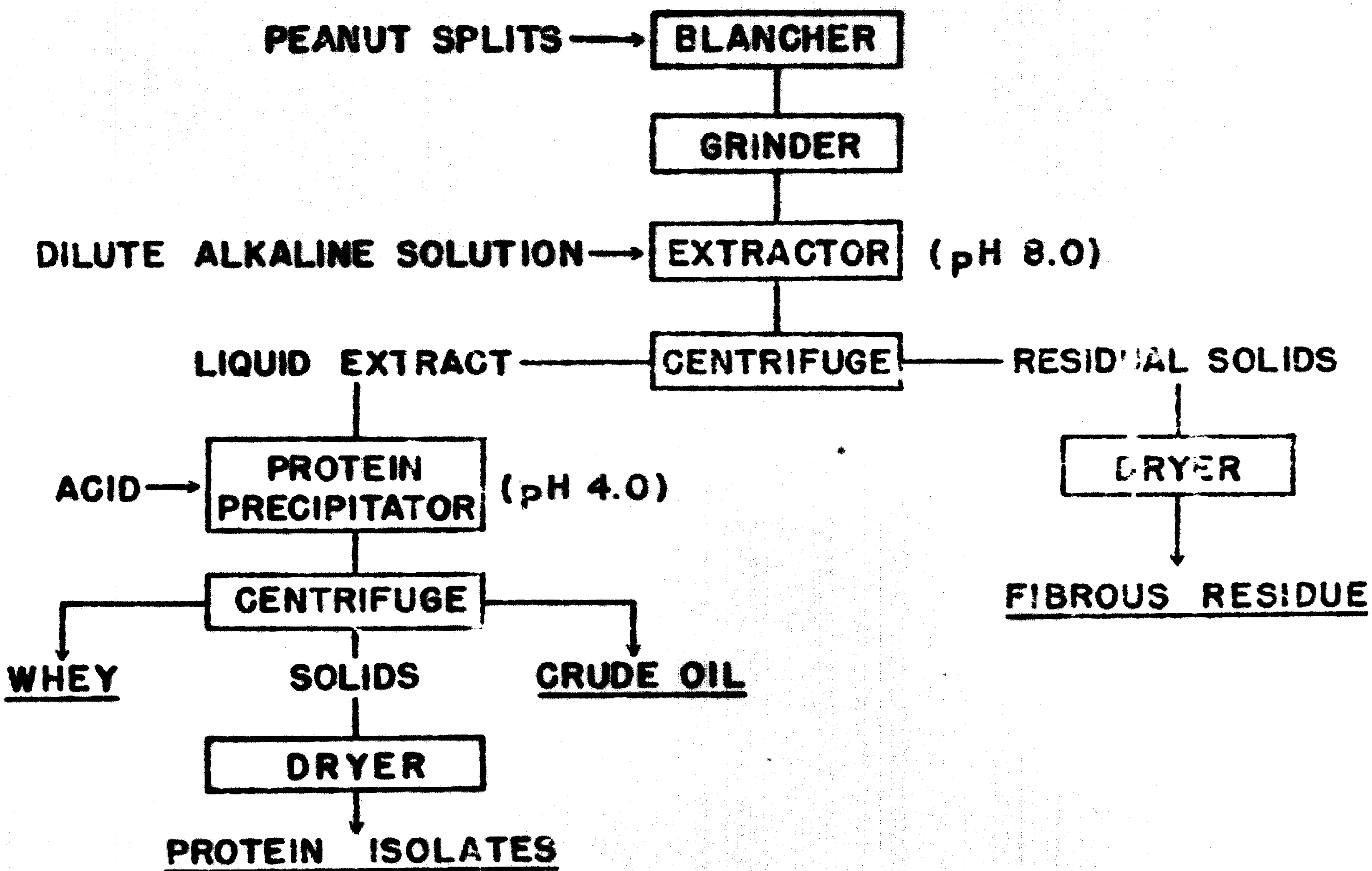

PEANUT SPLITS
BLANCHER
GRINDER
DILUTE ALKALINE SOLUTION
EXTRACTOR
(pH 8.0)
CENTRIFUGE
LIQUID EXTRACT
RESIDUAL SOLIDS
DRYER
FIBROUS RESIDUE
ACID
PROTEIN PRECIPITATOR
(pH 4.0)
CENTRIFUGE
WHEY
SOLIDS
CRUDE OIL
DRYER
PROTEIN ISOLATES

FIGURE 10

PRODUCTION OF SPUN FIBER PRODUCTS

Soy Protein Isolate Solution

Spin into Coagulating Bath

Protein Fibrils

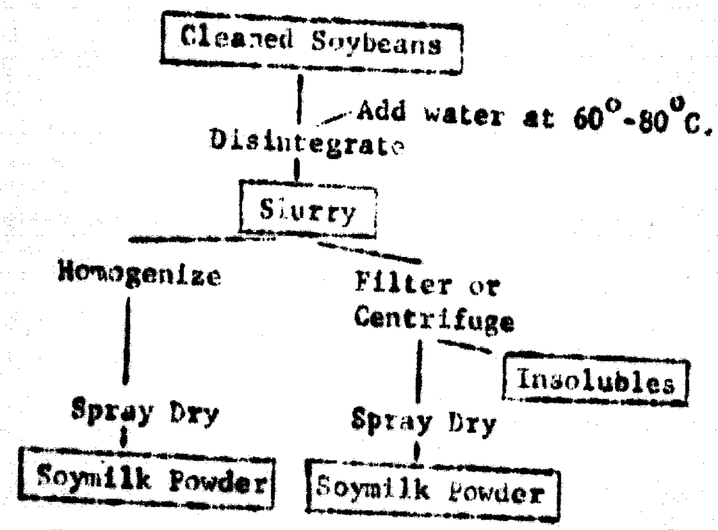
Blend with Fat, Flavors, Coloring Agents, Binders, Stabilizers

Form into Granules, Cubes, Slices

Fabricated Food Product

FIGURE 11

PRODUCTION OF SOYMILK



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