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SOYBEAN PRODUCTION, PROCESSING AND UTILIZATION IN A MODERN AGRO-INDUSTRIAL ECONOMY 1/

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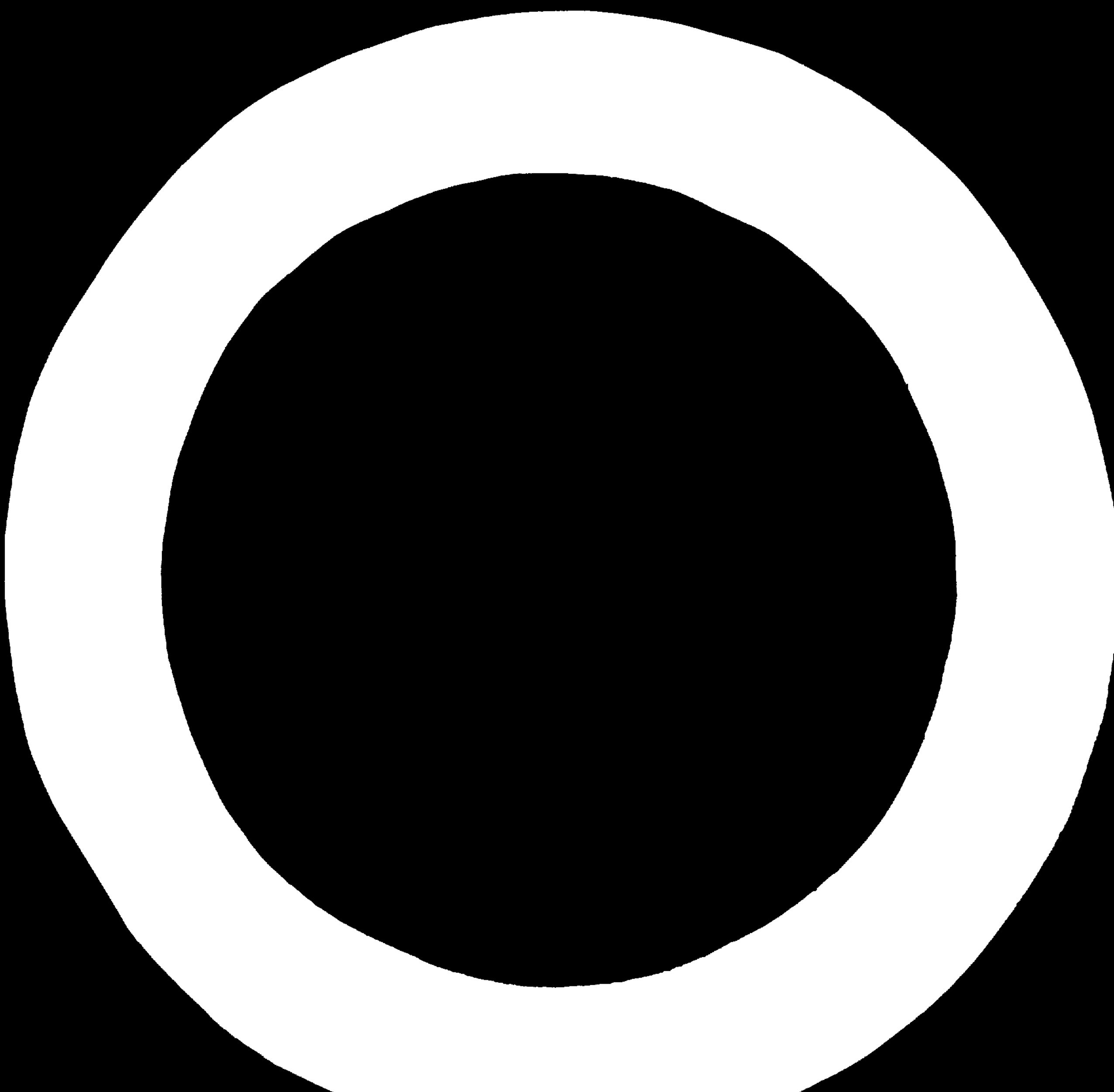


"SOYBEAN PRODUCTION, PROCESSING AND UTILIZATION IN A MODERN AGRO-INDUSTRIAL ECONOMY"

Those who have been concerned about the relationship between population growth in the world and food supply, have recognized that conventional protein foods such as dairy products, meat and eggs cannot be relied upon to supply those demands in the world picture. Even in the more affluent nations, such as the United States, where we have had overall adequate protein supplies, and will have good supplies for the foreseeable future, economics tends to dictate changes in ingredients which are used in processed foods.

There was a time when the U.S. agricultural production was at such a level that we had large surpluses, so we were able to supply large quantities of food and feed grains to other areas of the world without difficulty. However, the situation has rapidly changed and for practical purposes we have no surpluses and are not likely to have any real surpluses ever again.

The most important U.S. farm crop of the last 30 or 40 years, which is responsible for the livestock economy we enjoy in the United States, is the soybean.

Table 1 shows that since 1924 the U.S. production of soybeans has increased from 135,000 metric tons to over 42,000,000 metric tons in 1973. The average in 1924 was .74 metric tons per hectare and in 1973 averaged 1.87 metric tons per hectare. The 1973 average yield in the State of Illinois with harvest from over 3.7 million hectares was 2.2 metric tons per hectare and in the State of Iowa with harvest from over 3.2 million hectare was almost 2.3 metric ton per hectare.

The big use for protein in the form of soybean meal is for animal feed purposes but increasing quantities of the soy protein-containing portion of the soybean are being used in various ways as human food. New technology and economics will see a sharp rise in the increase in soy protein-containing products for human food.

Table 2 presents figures for protein concentrate production and feed use of these concentrates in the United States for years 1962-63 and 1972-73. The figures for feed use represent domestic production plus imports, minus estimated food, industrial and non-feed uses.

This Table indicates that of the protein concentrates used in animal feed, soybean meal makes up over 62% of the total, but, on a protein basis, would be considerably higher.

Based on figures of 1972, the consumption of soybean meal in the United States on a percentage basis was approximately as follows: poultry - 42%, hogs - 19%, beef cattle - 13%, dairy cattle - 11% and other uses - 15%.

While practically everywhere in the world, there is a great desire for meat products, with increasing affluence in some areas of the world, the demand per capita for meat products is increasing and so is the price. With the projected population increase, it does not appear possible for the world to supply sufficient protein in the form of animal products to satisfy nutritional needs and demands.

Table 3 shows the red meat consumption per capita in 1971 for selected areas of the world. It does not seem likely, even if everyone could afford to purchase meat products, that it will be at all possible to bring the level of red meat on a per capita basis up to the levels of Canada, the United States, some areas of Oceania and South America.

Table 4 gives some figures on the number of people who could theoretically be fed for one day by protein from various sources based on production from one hectare of land in one year. It is obvious from these figures, that the amount of land to produce protein as animal protein is much less efficient than vegetable protein. Further, when one considers that the cereal grains are relatively low in protein and relatively poor in protein quality, it is obvious that the use of land for growing soybeans would give us the best land use for protein production.

Chart 1 shows the efficiency of nitrogen conversion through feeding protein sources (largely vegetable) to animals. For an approximation, it takes 4 to 5 pounds of protein in the form of animal feed to produce 1 pound in the form of chicken meat. For swine it takes 7 pounds of protein in the form of feed to produce 1 pound of meat protein. To convert feed to milk protein, it takes approximately 4 pounds of protein in feed to produce 1 pound of protein in milk.

Looking at the situation in another way, Chart 2 illustrates in a general way man's competition for food with feed requirements for food producing animals. Man's competition is for some of the types of proteins which are used in supplemental protein feeding, namely, protein concentrates such as that supplied by the soybean, sunflower, etc.

Tables 5, 6, 7 and 8 illustrate the improvement in nutritional value of feed before and after soy protein concentrates (as well as other concentrates) were available in quantity in the United States. While other factors such as better knowledge of animal nutrition with regard to vitamin and mineral requirements, the advent of antibiotics, etc., contributed to this improved feed conversion and weight gains of various animals, there is no question that soybean meal contributed greatly to this improvement. For example in broilers, when one compares the 1931 ration with the 1969 ration the average increase in size of broilers in an 8 week feeding period was 35% using about 23% less feed. Similar results are indicated on turkeys, swine and beef cattle.

Tables 9 and 10 show soybean production and average yields in selected countries for approximately the past 10 years. This data indicates that soybeans can be grown in areas of Eastern Europe with good yield.

Tables 11, 12 and 13 indicate the imports to various countries in Eastern Europe for soybeans, soybean meal and soybean oil. These figures indicate that processing of soybeans to produce oil and meal has been increasing over the past several years and that soybean meal and oil appears to have proved to be useful products. The meal portion has been used almost exclusively for animal feed use.

Table 14 shows production of sunflower seed and yields in selected countries. In comparing the data in Table 1 on soybean yields with the information in Table 14 on sunflower yields, while some figures indicate very good yields for sunflower, there are other areas where the yields for sunflower are not nearly as high as for soybeans in the United States. It is possible that by selection of varieties and using the best agronomic procedures, that both soybean and sunflower yields can be and will be improved in Eastern Europe.

In Table 16 a comparison is made on the amount of soybean oil and soy proteins produced per hectare in the United States, in comparison to some data for Bulgaria and Yugoslavia. These figures show that on the average, the figures for Bulgaria and Yugoslavia are approaching those of the United States.

Using the figures for U.S.S.R., the largest producer of sunflower seed, for average yield in 1972 and using the figures for yields of soybeans in the United States, the production of sunflower protein per hectare in Russia, Table 17 shows the sunflower protein production of 0.28 metric tons and oil production of 0.564 metric tons in comparison to the production of 0.711 metric tons of soy protein and 0.357 metric tons of oil per hectare.

Table 18 presents data in comparing the production of protein and oil per hectare from sunflower and soybeans in Yugoslavia. This data indicates that oil production per hectare from sunflower is about 2.8 times that from soybeans and protein production from soybeans is around 1.9 times that from sunflower.

There is no question that both the protein and oil are of importance, so it is a matter of evaluating the relative importance from an economic and nutritional standpoint for both the protein and oil.

There is no question that the protein in sunflower meal, when used as a concentrate for supplementing cereal grains, feed efficiency can be improved. There still seems to be some disagreement among nutritionists on the relative merits of sunflower meal as a complete replacement for soybean meal in rations. Evidence seems to be that care must be taken in heating sunflower meal whereby excess heat can have an adverse effect on the nutritional value of protein in sunflower meal, particularly with regard to lysine.

With current methods of processing sunflower, there is generally a higher fiber content which may adversely affect the feeding results on young swine and poultry. 25 years or so ago, most of the soybean meal produced in the United States was made by solvent extraction of the flaked beans containing all of the hulls to produce what is known as a 44% protein soybean meal. Animal nutrition studies have indicated that the removal of the fiber results in better feed efficiency for poultry and young swine, so large quantities of soybeans are processed whereby hulls are removed to produce a meal with 49 to 50% protein. While there is no general reporting on the quantities of each type of meal being marketed, experts in marketing estimate that approximately 35% of the total meal production in the United States is marketed as 49 to 50% protein meal. Some soybean processing plants produce only the high protein meal, some produce only 44% protein meal and other may produce both types of products.

In perusing the literature with regard to amino acid composition of protein products, one will find that there is variation from various literature sources. Table 19 gives approximate amino acid composition of soy and sunflower protein based on 16 grams of nitrogen. Using a factor of 6.25 x N, this would represent 100% protein. In 1957, the FAO/WHO (Food Agricultural Organization/ World Health Organization) committee on protein requirements established a provisional pattern for essential amino acids based on what they considered to be the average minimal requirement of adults and infants for each of the individual essential amino acids. This pattern was established with the view that the protein quality of foods or combinations of the foods might be predicted by comparison of the portion of the essential amino acids in such foods or food combinations with this provisional pattern. As a result of experimental work carried on, this pattern was revised in 1965, as shown in Table 19. If we accept the amino acid analysis as shown for soy and sunflower protein, it is obvious that, at least theoretically, using a combination of soy and sunflower protein-containing products would give an overall better amino acid balance, in that the soy would furnish lysine to the sunflower and sunflower would be furnishing the sulfur-containing amino acids for soy. While the requirements of food producing animals are somewhat different from the human, it still would appear that the combination of soy and sunflower meal along with other ingredients, should result in a better quality feed than using either one alone.

In the United States, sunflower protein has not been used for human food, although roasted and salted sunflower seed products are on the market to be used as a snack item. It is my understanding that such products are available in Eastern Europe, but also sunflower is used for making a confectionery product, namely, halvah. In the United States and some other areas of the world, the halvah type product is usually made using sesame seed.

Soy protein-containing products have been used for centuries as food products in Asiatic countries. With the advent of solvent extraction and other technology, a variety of protein-containing products have been produced in the United States and elsewhere. In Japan, where traditional Oriental foods are still being used, they, too, are developing new ways of taking advantage of the protein from the soybean.

In the United States, processed whole soybeans, which have been dehulled, are being marketed as snack items to the consumer. While this use of the soybean still is relatively small, the major soy protein-containing products are defatted soy flour and grits, full fat soy flour, expeller produced low fat soy flour and grits, soy protein concentrates, isolated soy protein, texturized soy protein and spun protein fibers. Tables 20 and 21 show the typical composition of these soy protein-containing products.

Table 22 shows the estimated current annual production of the various edible soy products in the United States. The production of soy flour and grit products have essentially doubled in the last 10 years. For practical purposes the other products were essentially at a zero level of production 10 years ago.

Before getting into further discussion regarding the various edible soy protein-containing products, Chart 3 shows the general steps involved in producing various products from the soybean.

In processing soybeans to produce meal and oil, the steps through solvent extraction are exactly the same as for producing flakes for making edible products. However, if soybeans are to be processed for producing edible products the plant should be designed in such a way as to permit good sanitary practices. Generally, it is necessary to do a better job of bean cleaning for edible products than for producing meal for animal feed purposes. When a plant is operated for producing oil and meal for animal feed, the desolventizing is usually carried out in one unit referred to as a desolventizer toaster. In this unit the solvent is removed from the solvent wet flakes and the meal heat processed to destroy anti-growth factors, such as the anti-trypsin factor, and to improve the nutritional quality of the protein. In the desolventizer toaster unit, the meal is heat processed in such a way that the urease activity, when determined by a standard procedure, is less than 0.15. At this urease activity level, there is also a correlation with the amount of protein which is water dispersible under a given condition of tests.

There have been a number of terms used to designate the amount of protein in the product which is water dispersible, but the more commonly used terms are PDI (protein dispersibility index) and NSI (nitrogen solubility index). The procedures used for determining these values have been published in the "Official and Tentative Methods - American Oil Chemists Society". For purposes of this discussion, the term PDI will be used. When the urease activity of a heat processed soy product is below 0.15, the PDI will generally be below about 30, which represents the percentage of the total protein in a product which is dispersible in water under the conditions of the determination. It is possible to overheat a soybean meal and harm the nutritional value of the protein. Generally the product should not be heat processed below a urease activity of around 0.05 or a PDI below about 5, if one wishes to have the optimum protein nutrition.

The use of soy flour and grits, soy protein concentrates and soy protein isolates in foods in the United States, has been primarily to take advantage of certain functional characteristics with nutritional value being secondary. Naturally, there have been exceptions to this, where nutritional value was of prime importance. This situation is changing. While functional value is of importance, the nutritional considerations also are now becoming of much more interest.

In the case of soy flour products, the functional characteristics are influenced by the PDI and particle size. Soy flour and grits are differentiated based on particle size. Those products which are ground to pass a 100 mesh U.S. sieve or finer are referred to as flour products, and those which are more coarsely ground and screened are referred to as grits.

Chart 4 is a general scheme for operation of the desolventizer-deodorizer toaster system to produce soy flour and grits.

Soy protein concentrates, by definition, are products which have been processed in such a way as to contain greater than 70% protein on a dry basis. The general scheme for their production is shown in Chart 5. There are 3 procedures which are currently being used to manufacture these types of products. In one process aqueous alcohol is used to extract the soluble carbohydrates, minerals, and other components. The concentrate produced by this procedure is generally considered to have the least beany flavor. Regardless of the PDI of the flakes used as starting material in this process, the proteins are denatured so that the PDI of the finished product is in the range of 5 to 15%. The concentrate produced by this process has very little beany flavor but does have the ability to absorb moisture and fat. This type of product is used in breads, meat products, breakfast cereals, calf milk replacers, etc.

The soy protein concentrates produced by the acid leach process are usually neutralized to a pH in the range of about 6.8 and spray dried. The acid leach concentrates, when so neutralized, have PDI values close to the original flakes or flour used for processing. This type of concentrate is used in a manner similar to the alcohol leach product, but does not seem to have a market in calf milk replacers, primarily due to higher price.

In the third process for producing concentrates, the flakes or flour are heated to such a point that the proteins are almost completely denatured so that straight water wash will remove solubles and give a product which has water and fat absorption properties, but very little in the way of other functionality characteristics.

The primary advantage of the concentrates over regular soy flour and grits is the higher protein concentration and better flavor. In the manufacture of these products, the soluble portion, if not recovered, constitutes a water pollution problem. Most of the companies producing these products concentrate the solubles and add them back to meal for use in animal feeds.

At the bottom of Chart 5 a general flow sheet is presented on the manufacture of isolated soy proteins. These products are high in protein, are generally bland in flavor, and have good functionality. Depending on the process, there will be differences in the functional characteristics of the isolates.

Since isolated soy proteins are essentially free of carbohydrates, fiber and fat, and also have a variety of other properties different from concentrates and soy flour, they can be used more successfully in imitation dairy-type products. Soy protein isolates do find extensive use as a binder and emulsifier in comminuted meat products.

Chart 6 shows the products from the soybean and uses of the various products in the United States. The figures in parenthesis indicate the typical yield from soybeans.

If soy flour or grit products are to be used as ingredients in foods which do not have any appreciable heating during their processing, the soy flour should be made from flakes heat treated to have a PDI of below about 30. The reason for this is that if the PDI is higher, the optimum nutritional value would not be obtained due to the presence of the anti-trypsin factor. In the case of food products that do go through heat treatment during the manufacturing process or which will be heated during the preparation of the food before consuming, the higher PDI types of soy flour may be used to take advantage of the functional characteristics these products possess. The heat treatment during processing of these products in manufacture or cooking before consumption will destroy the anti-trypsin factor so the nutritional value of the products would be satisfactory.

The textured soy protein products which are produced by a thermoplastic extrusion process have come into existence during the past few years. Chart 7 gives a diagramatic sketch of the process used for making these products. The textured soy proteins are produced from defatted soy flour and have a laminated structure and are produced as dry products, which, when rehydrated, have textural characteristics similar to meat. They may be colored, flavored and fortified with vitamins and minerals. These products have found acceptance as a partial substitute for ground meat and were approved for use in the School Lunch Program in the United States in 1971. The dry textured soy protein products are hydrated with water using 2 parts of water for each part of the textured soy protein. The hydrated product is then mixed with ground meat on the basis of 30 parts of the hydrated product with 70 parts of meat. During the 1971-72 school year, the usage on the dehydrated basis was a little over 3 million kilograms and last year estimated at 27 million kilograms. The savings over the purchase of all meat in the 1973 School Lunch Program is estimated at 40 million dollars. These products are also being used in ground meat products being sold direct to consumers. Recently, packaged flavored and colored textured soy protein products have appeared on the market as complete replacement for meat in sauces, casseroles, etc. where ground meat products are usually used. Estimates by the United States Department of Agriculture are that by 1980 these products, including soy protein concentrates, isolates and soy flour and grits could be equivalent to 8% of the U.S. total red meat product.

Studies in humans have shown that the use of textured soy protein products in combination with meat give nutritional results which are not essentially different from that obtained with 100% meat products.

Another more sophisticated type of textured soy protein product is that produced from isolated soy protein whereby the dispersion of the protein is forced through very fine openings into a coagulating bath whereby fibers are formed. These products are then pulled off in what are referred to as "tows" and processed to make different types of simulated meat and fish products. Chart 8 represents the scheme for the soy protein fiber process. These products are available on the consumer market in the U.S. as bacon-type bits, non-meat sausage-type products, of both the pattie and link type, and as slices simulating ham. The bacon-type products are a dry flavored product used for any use where fried bacon bits might be desired. The flavored simulated meat fiber-type products have recently appeared in the supermarkets as a frozen item to be warmed and eaten in a manner similar to meat. There are also simulated chicken, ham, beef, etc. products being sold as frozen items in the institutional field to be used as complete or partial replacement for meat in any way that a cubed or chopped meat product might be used.

A major meat processor is test marketing a frankfurter-type product where reportedly 50% of the protein is isolated soy protein. This product is apparently being well accepted in the test markets, and may eventually be marketed on a national basis.

While it has been well accepted that soy protein, by itself, is a very good nutritional protein, and the amino acid balance of the protein is such that in combination with cereal proteins, cereal containing protein products can be improved from the standpoint of protein quality, and total protein content of such products can be increased, the major problem has been the flavor of soy flour and grits. This has had a limiting affect on its use. In more recent years, improvements have been made in the processing to produce soy flour and grits, so the flavor is somewhat less of a problem. As a result, further processing to produce soy protein concentrates and isolates with less of a flavor problem have resulted. In the case of the textured soy protein products, the processing does give some flavor improvement, but still they are not perfect. When the textured soy protein products are used in combination with meat, it is common practice to add seasoning ingredients which "coverup" the undesirable soy flavors.

Scientists agree that part of the flavor problem in making defatted products is that in the current methods where the beans are cracked and flaked, the lipoxygenase system is such that, within a very short period of time, reactions take place with the fat tied to the protein in the form of lipo-proteins so that flavors develop which are not easily removed during subsequent operations. As a result of this finding, in making full fat and low fat soy flour, the beans are heat processed before cracking and further processing in order to inactivate the lipoxygenase system. As a result, the full fat products which are produced by heat processing of the beans followed by hull removal and grinding do not develop the beany, bitter flavor, but depending on the degree of heat processing have a pleasant nutty characteristic. This type of flour is being used in baked products, to a limited extent in calf milk replacers and as a partial replacement for peanut butter in baked products using peanut butter and confectionery items and soy milk products used for feeding babies allergic to cows milk.

Another type of soy flour with good flavor is a low fat soy flour which is produced by heat processing the beans in a manner similar to that for making full fat soy flour, followed by dehulled and expelling part of the oil to yield a soy protein-containing product with around 6% fat and 50% protein. This type of product is being used in comminuted meat items, pet foods, baked products, soy milk and other food products where the presence of the fat is not detrimental.

One of the major uses of soy protein-containing products in the United States is in pet foods. There are a variety of different products produced, including canned, semi-moist and dry. The dollar retail sales volume of these products is over $1000 million. While there is no general reporting on the quantities of soy protein products used it is estimated that the overall use of soy as meal, grits and flour and textured soy proteins would be in the range of 330,000 to 450,000 metric tons per year. On a protein basis, this undoubtedly makes up over 50% of the total protein consumed by pets, mainly dogs.

In many food products soy lecithin is used as an additive. In the U.S. where soy flour and lecithin are both used as ingredients in the same food product, it is common practice to add the lecithin to the soy flour at levels up to 15% as a convenient way of handling the lecithin. By way of general interest it is estimated soy lecithin production in the U.S. is in the range of 34,000 to 41,000 metric tons, on a crude lecithin basis. Lecithin of various types are used in a wide variety of food and industrial products.

For many years soy milk products have been available as dry and canned or liquid products for feeding babies who are allergic to cows milk and for others, such as vegetarians and certain religious groups, who do not desire animal protein.

It has been estimated that in 1973 about 10% of the infants in the United States will be fed formulas based on soy. 25 or 30 years ago infant formulas were developed based on producing soy milk directly from beans, with full fat soy flour and low fat expeller type soy flour. While these products are still being produced, in the 1960's, when isolated soy proteins as proteinates were available, it became possible to make a nicer looking product with good color, and better general acceptability insofar as the mother was concerned. These products are formulated in such a way as to give good caloric distribution insofar as protein, fat and carbohydrates are concerned, with the addition of methionine, minerals and vitamins.

The soy milk products based on isolates, for feeding infants result in better formed and less odorous stools. In the soy flour products, the presence of stacchyose and raffinose results in the development of microbial flora, different from that produced if these carbohydrates are not present. In manufacturing of the soy protein isolates, these carbohydrates are removed.

In the beverage product area, sterilized soy milk products have been sold for many years in Asian countries. In Hong Kong, one such soy-milk product manufactured by a local company reportedly outsells carbonated beverages. It was projected that this past year around 150 million bottles were sold. These products are made from whole soybeans with sugar, flavor, vitamins and minerals added.

For a number of years the U.S. Government has purchased a product known as "CSM". which is a corn-soy-non-fat milk product, but with the shortage of non-fat milk and the high prices, a new product has been formulated based on sweet cheese whey and about 36.5% full fat soy flour, along with other additives, which is intended for use as a beverage in the AID (Agency for International Development) Program. This project is just now getting underway, and government purchases have been projected at approximately 1 million pounds a month during the next year with an eventual growth to around 10 million pounds a month in the next 2 or 3 years.

For at least 25 to 30 years, soy flour products have been used as a partial replacement for milk in milk replacer products for feeding young animals, with perhaps 95% of this type of product being used for feeding calves. Soy protein concentrates are also widely used in calf milk replacer products, and there is a limited amount of isolated soy protein used in such products. The isolates are not used so much for nutritional value, but rather to take advantage of certain functional characteristics in producing these products.

In feeding baby calves for herd replacement, generally soy flour is used up to levels of around 10%. Baby calves are allowed to feed on the mother cow for 2 or 3 days and then fed on milk replacer products for about 3 to 4 weeks at which time they then begin to get solid feed. In the case of calves raised for veal, they want to get a fast weight gain so the animals are essentially force fed for 10 to 12 weeks, but up until recently very little soy protein was used in feeding veal animals. However, it is reported that due to the high prices for non-fat milk, that small amounts of soy flour are used in some products.

In the case of herd replacement animals, there is not as much interest in rapid gain, but bone structure is most important, so the mineral content, particularly calcium, is of importance.

Some milk replacer products are used for feeding baby pigs, where they are fed on colostrum for about 3 days and then may be fed a milk replacer. After about 2 weeks they are switched to a high milk pellet which will contain whey and non-fat milk and may contain up to 5 to 10% soy flour.

There are some liquid products fed to dogs which may consist of combinations of whey, sodium caseinate and soy flour, but these are special products usually sold through veterinarians.

In the baking field one type of soy flour which has been used extensively in the United States and Europe for many years is that referred to as "enzyme active". The enzyme active type product is produced as a defatted product whereby the desolventizing is carried out in such a manner that there is very little moist heat involved so that the protein denaturation is at a minimum and the enzyme activity retained. Another type of enzyme active flour is the full fat type, whereby the beans are cleaned, dehulled and ground to a fine flour. The enzyme active flour is usually used at a level in the range of 0.5 to 0.75% based on the wheat flour. This type of flour does have a beany, bitter flavor, but at the levels of use and through the heat given to the product during baking, this flavor does not seem to come through in the final product. The reason for using this type of flour is to take advantage of the lipoxidase enzyme systems whereby a bleaching effect is obtained on the pigments of the flour. The soy lipoxidase enzyme system results in the formation of hydroperoxides which in turn react to give a bleaching effect giving an improvement in crumb color. It is also stated that there is improvement in the crumb softness, keeping quality and flavor. Other types of soy flour used in bread baking, cakes, etc. are types which have been heat processed to some extent and do not have the lipoxidase activity, but which still have a PDI in the range of 60 to 70. These flours are used primarily for other functionality characteristics such as water absorption and are used at higher levels.

It has been common practice in the United States to use non-fat milk solids in breads at levels from 3 to 6%. The non-fat milk has been used to help with crust color, what some people feel is better flavor, and for nutritional improvement.

Ten years or so ago non-fat milk was available in the United States at around 15¢ per pound, but more recently has been in the 70¢ per pound range. As a result, we now have an example of economics coming into play whereby blends of cheese whey, non-fat milk solids, sodium caseinate and soy flour are used as non-fat milk solids replacement. These blends may sell at one third to one half the price of non-fat milk solids and are produced in such a way that they can be used as direct replacement for non-fat milk. This is not only true in the baking field, but in other areas such as the confectionery field, sauces, meat products, etc.

When soy flour is used at higher levels than 1 or 2% in bread, based on the wheat flour, as one increases the soy flour level, the volume of the finished loaf gradually decreases in proportion to the amount of soy flour added. In recent years, it has been found that when certain emulsifiers are added along with the soy flour, this affect on volume can be overcome. The emulsifiers are the stearoyl-2-lactylate type. It is claimed that with the addition of this emulsifier, the affect of flavor is also overcome.

The normal protein efficiency ratio (PER) of white bread in the U.S. is in the range of 0.7 to 1.0 with a protein content of about 8%. When bread is fortified with about 6% soy flour, the PER is increased to about 1.3 and the protein content to 10%. With 12% soy flour added the PER is increased to 1.9 and the protein content will be around 11.5%. In cookies in the United States, the protein content is usually about 5% and the PER around 0.5. When cookies are produced using 12% soy flour, based on the wheat flour, the protein content will be increased to about 8% and the PER to around 1.5.

Currently, the price of wheat flour in the United States is around 11¢ per pound, and defatted soy flour in the range of about 9¢ per pound. This would mean that fortification can be carried out to give overall improvement in protein quality at a lower cost than using wheat flour alone.

When soy flour is used in baked products, it is necessary to make some adjustments in the processing, in that mixing time is usually decreased and one should add about one additional pound of water for each pound of soy flour used, over what normally would be used in preparing the food product.

Soy flour products can also be used to fortify pasta or macaroni-type products. Although the addition of soy flour does result in some color and textural changes, pasta products are being produced using soy flour to improve the nutritional characteristics in products being used in overseas programs, School Lunch Programs and other feeding programs in the United States. In pasta products in the U.S., durham flour is the product of choice. Feeding studies have shown that when 100% durham is used, the PER is around 1.27, fortified with 12.5% soy flour increases the PER to 1.94 and with 25% soy flour to 2.39. The soy fortified products would contain approximately 50% and 100% more protein in a fortified product, but the quality of the protein also is increased in almost a proportionate amount.

In certain comminuted meat products in the United States, there are standards of identity, whereby in a standard product the quantity of soy which may be used is limited. For example, in frankfurters, when soy flour or soy protein concentrates are used, they may be used up to a maximum of 3.5% and isolates are limited to 2%. However, in those meat produce which do not have a standard of identity, there is no limitation to the usage, but the ingredients used must be listed on the label in order of the quantity in a given food product. The level of use in so-called "non-specific" mea's would be dependent on the characteristics and quality desired in the product to be marketed.

With the shortages and high prices for dairy products, there is a considerable activity in the possible use of soy beverages or soy milk-type products as partial or complete replacement in all types of dairy foods, including cheese, ice cream, yogurt, etc.

It appears that the soy protein products, which once were considered as "ersatz" items, now are being recognized as good food ingredients and will stand on their own as good nutritional products to be used as ingredients in foods or as foods by themselves as replacement for meat and dairy products in the human dietary.

TABLE 1

U.S. PRODUCTION AND YIELDS OF SOYBEANS[1]

	Production (1000 metric tons)	Yield (metric tons/hectare)	Range
1924	135	.740	.370-1.009
1944	5,229	1.264	
1964	19,076	1.533	
1973	42,640	1.870	1.278-2.287

[1] Soybean Digest Blue Book - 1974

TABLE 2

PROTEIN CONCENTRATE PRODUCTION - U.S. [1]

(1000 M.T.)

	1962-1963		1972-1973	
	Production	Feed Use[2]	Production	Feed Use[2]
Soybean Meal	9,624	8,290	15,158	10,861
Cottonseed Meal	2,477	2,446	2,057	2,018
Linseed Meal	363	297	327	192
Peanut Meal	72	72	164	163
Copra Meal	84	84	91	91
Gluten Feed and Meal	1,241	1,241	1,573	1,573
Tankage and Meat Scraps	1,758	1,760	1,571	1,578
Fish Meal	271	669	338	442
Dried Milk Products	194	194	299	299
Other Milk Products[3]	519	519	317	317
TOTAL	16,603	15,572	21,895	17,534

[1] Soybean Digest Blue Book - 1974

[2] Domestic production plus imports, minus estimated food, industrial and non-feed uses.

TABLE 3

RED MEAT CONSUMPTION/CAPITA 1971[1]

	Total Red Meat*	Beef & Veal	Pork	Mutton, lamb & Goat
U.S.	87.3	52.7	33.2	1.4
Canada	74.6	42.3	30.5	1.8
European Community	55.5	25.0	28.2	1.4
Eastern Europe				
Bulgaria	31.8	10.9	11.8	9.1
Czechoslovakia	53.7	19.1	34.1	0.5
Hungary	50.1	9.1	40.5	0.5
Poland	40.9	15.5	24.1	0.9
Yugoslavia	35.0	11.8	20.5	2.7
U.S.S.R.	40.5	22.3	13.6	4.5

* Includes horsemeat

1 U.S.D.A. - F.A.S. Bulletin FLM 2-73

TABLE 4

NUMBER OF PEOPLE WHO COULD THEORETICALLY BE FED FOR ONE DAY BY PROTEIN FROM VARIOUS SOURCES BASED ON PRODUCTION FROM 1 HECTARE OF LAND IN 1 YEAR ASSUMING 60 g. PROTEIN INTAKE/CAPITA/DAY

Protein Source	Number of[1] People
Beef	190
Pork	319
Poultry	457
Milk	583
Rice (white)	2469
Cottonseed	1793
Peanuts (Groundnut)	2536
Wheat Flour (white)	2712
Sesame	2620
Corn flakes	2828
Rye flour (whole)	3186
Sunflower kernels	3314
Wheat flour (whole)	3391
Oat meal	3445
Corn meal (whole)	3536
Rice (brown)	3926
Dry beans	4315
Potatoes	5239
Split peas	6901
Soybeans	9075
Algae	43,200-154,000
Yeast	3,275,000

1 Animal protein data calculated from data - Comparative Proteins - D. Catron - American Soybean Association Meeting - 1967

Other data based on U.S.D.A. world average yields - 1971

TABLE 5

BROILER GROWTH AND FEED CONVERSION IN 8 WEEKS

Type of Ration	Weight Gain (1 Kilogram)	Feed[1] Conversion
1931	1.28	2.75
1969	1.73	2.10

1 Amount of feed/unit gain

TABLE 6

TURKEY GAIN AND FEED CONVERSION

Type of Ration	Gain from Hatch To 6 Weeks of Age (Kilograms)	Feed Conversion
1930	.975	2.30
1969	1.260	1.73

TABLE

SWINE GROWTH AND FEED CONVERSION

Type of Ration	Days Fed	Average Initial Weight (Kilograms)	Average Final Weight (Kilograms)	Average Daily Gain (Kilograms)	Feed Conversion
1908	105	18.2	28.4	.095	8.11
1958	105	18.7	96.4	.74	3.18
1929	79	20.5	62.7	.54	3.29
1969	79	20.5	72.9	.66	2.92

TABLE 8

CATTLE GROWTH AND FEED CONVERSION

Type of Ration	Days Fed	Initial Weight (Kilograms)	Final Weight (Kilograms)	Average Daily Gain (Kilograms)	Feed Conversion
1908	252	189.8	392.3	.80	9.0
1958	252	170.7	459.4	1.14	6.3

TABLE 9

SOYBEAN PRODUCTION - SELECTED COUNTRIES[1]

	Production (in 1000 Metric Tons)			
	1962-66 Average	1971	1972	1973 (Indicated)
U.S.	20,920	32,005	34,915	42,633
Romania	6.21	165.0	186.0	234.0
Yugoslavia	8.98	4.0	5.99	-
Bulgaria	-	-	-	15.0
U.S.S.R	436.8	535.0	260.0	400.0

1 Soybean Digest Blue Book - 1974

TABLE 10

SOYBEAN YIELDS - SELECTED COUNTRIES[1]

	YIELD (Metric tons/hectare)			
	1962-66 Average	1971	1972	1973 (Indicated)
U.S.	1.634	1.849	1.883	1.883
Romania	.686	1.123	1.708	-
Yugoslavia	1.358	.827	1.641	-
Bulgaria	-	-	-	1.7
U.S.S.R.	.511	.619	-	-

1 Soybean Digest Blue Book - 1974

TABLE 11

U.S. SOYBEAN EXPORTS TO EASTERN EUROPE[1]

(in metric tons)

	1969	1970	1971	1972	1973[2] (Through Dec.)
ulgaria	463	0	0	354	0
zechoslovakia	12,791	3,130	0	0	7,239
ast Germany	0	15,431	0	0	0
ungary	13,581	32,305	0	0	0
oland	134,118	83,361	65,943	145,086	33,012
.S.S.R.	0	0	0	858,404	0
ugoslavia	0	30,672	27	0	0
ther	0	15,431	0	19,459	0
TOTAL	160,953	180,330	65,970	102,330	40,251

Soybean Digest Blue Book - 1974

U.S.D.A. - F.A.S. Bulletin

TABLE 12

U.S. SOYBEAN MEAL EXPORTS TO EASTERN EUROPE[1]

(in 1000 metric tons)

	1969	1970	1971	1972	1973[2] (Through Dec
Bulgaria	36.6	29.8	0	0	0
Czechoslovakia	32.8	90.2	65.6	173.3	18.1
Hungary	154.8	141.5	85.4	84.2	2.7
Poland	99.7	101.9	59.7	305.7	58.1
Yugoslavia	157.7	169.5	105.4	138.1	65.3
Other	5.2	0	90.6	166.6	34.5
TOTAL	486.8	532.9	406.7	875.9	178.7

1 Soybean Digest Blue Book - 1974

2 U.S.D.A. - F.A.S. Bulletin

TABLE 13

U.S. SOYBEAN OIL EXPORTS TO EASTERN EUROPE[1]

(Metric Tons)

	1969	1970	1971	1972	1973[2] (Through Dec.)
oland	4536	3175	0	0	0
ugoslavia	454	122,923	90,265	53,070	3992
her	454	0	0	0	0
TOTAL	5444	126,098	90,265	53,070	3992

Soybean Digest Blue Book - 1974

U.S.D.A. - F.A.S. Bulletin

TABLE 14

SUNFLOWER PRODUCTION - SELECTED COUNTRIES

	Production[1] (In 1000 Metric Tons)				Yield[2] (Metric Tons/Hectare		
	1970	1971	1972 (Preliminary)	1973 (Indicated)	1970	1971	1972 (Indicated
U.S.	84.7	185.0	287.4	-	1.013	1.025	-
Canada	25.1	77.0	77.0	-	.888	.795	-
Bulgaria	407.0	455.0	483.0	525	1.360	-	2.0[3]
Hungary	81.0	152.0	132.0	-	.903	1.103	-
Romania	769.6	791.0	848.0	875	1.276	-	-
Yugoslavia	264.0	347.0	277.0	-	1.364	1.900	-
U.S.S.R.	5652.0	5200.0	4627.6	5500	1.183	1.168	1.218

1 World Agricultural Production & Trade-U.S.D.A-F.A.S. - Aug. 1973

2 U.S.D.A. - F.A.S. Bulletin FFO 16-72

3 Bulgarian Ministry of Agriculture

TABLE 15

ANALYSES OF SUNFLOWER SEED (AS IS BASIS)

	Canadian[1] High oil Sunflower Seed	Bulgarian[2] Seed
	%	%
Hull	25	23
H_2O	6.1	7.0
Protein	18.2	17.0
Oil	42.7	46.5

1 Averages from - Compositional Data on Sunflower Seed - J.A.O.C.S. 45 876 (1968)

2 Private Communication - Peter Petrov - CNIRD - Bulgaria

TABLE 16

OIL AND PROTEIN PRODUCTION/HECTARE

	1973 Average in Metric Tons	1973 Range (Metric Tons)
Soybean Production (U.S.)	1.870	1.278-2.287
Soy Oil Production	.337	.230- .412
Soy Protein Production	.711	.486- .869

	1973 Bulgaria	1972 Yugoslavia
Soybean Production	1.7	1.641
Soy Oil Production	.306	.295
Soy Protein Production	.646	.623

TABLE 17

COMPARISON OF PROTEIN AND OIL PRODUCTION (IN METRIC TONS)/HECTARE FROM SUNFLOWER IN U.S.S.R. (BASED ON 1972 AVERAGE YIELD) AND FROM SOYBEANS IN THE U.S. (BASED ON 1973 AVERAGE YIELD)

	U.S.S.R. SUNFLOWER	U.S. SOYBEAN
Average yield	1.218	1.870
Protein production	.280	.711
Oil	.564	.337

TABLE 18

COMPARISON OF PROTEIN AND OIL PRODUCTION/HECTARE FOR SUNFLOWER AND SOYBEANS IN YUGOSLAVIA

	Metric Tons
Soybean Production (1972)	1.641
Soy Oil	.295
Soy protein	.623
Sunflower Production (1971)	1.900
Sunflower oil	.833
Sunflower Protein	.323

TABLE 19

APPROXIMATE AMINO ACID COMPOSITION OF SOY AND SUNFLOWER PROTEIN IN GRAMS/16 g N.

Amino Acid	Soy Protein	Sunflower Protein	FAO Pattern 1965
Arginine	7.2	7.6	-
Histidine	2.5	2.2	-
Leucine	7.8	6.1	4.8
Isoleucine	4.4	4.0	4.2
Lysine	6.4	3.6	4.2
Methionine	1.2	1.7	1.7
Cystine	1.3	1.5	-
Methionine and Cystine	2.5	3.2	3.4
Phenylalanine	4.8	4.4	2.8
Tyrosine	3.2	2.7	2.8
Phenylalanine and Tyrosine	8.0	7.1	5.6
Threonine	3.7	3.4	3.3
Valine	5.0	4.8	2.8
Tryptophan	1.3	1.5	1.1
Glycine	4.0	5.0	-

TABLE 20

TYPICAL COMPOSITION OF SOY PROTEIN-CONTAINING PRODUCTS

	Whole Soybeans	Defatted Soy Flour	Soy Protein Concen-trates	Soy Protein Isolate
Moisture	10	7.0	4.0	4.0
Protein	38	52.0	68.	92
Fat	18	1.0	1.0	0.1
Fiber	5	3.5	4.5	0.1
Ash	5	6.0	5.0	3.5
Soluble Carbohydrates	18	14.0	2.0	0
Insoluble Carbohydrates	17	20	28.0	0.1

TABLE 21

TYPICAL COMPOSITION OF FULL FAT AND LOW FAT SOY PRODUCTS

	Full Fat	Low Fat
Moisture	5.5	5.0
Protein	40.5	50.0
Fat	21.0	6.0
Fiber	2.3	2.8
Ash	4.5	6.0
Carbohydrate	26.2	30.2

TABLE 22

ESTIMATED CURRENT ANNUAL PRODUCTION OF VARIOUS EDIBLE SOY PRODUCTS IN THE U.S.

	Metric Tons
Soy flour and grits	340,000 to 450,000
Soy protein concentrates	30,000
Isolated soy proteins	25,000
Textured soy proteins	90,000
Spun protein fibers	8,000

EFFICIENCY OF NITROGEN CONVERSION

STEP

1. AIR N_2 —— 90% —— FERTILIZER N
2. FERTILIZER/SOIL N —— 50% —— PLANT PROTEIN
3. BALANCED RATIONS —— 6-27% —— ANIMAL PROTEIN

	Av.	BYERLY (1965)	WILCKE (1966)	PRESTON (1966)
DAIRY COW (MILK)	27	30	23	28
BROILER	22	25	18	24
HEN (EGGS)	22	20	23	23
SWINE	16	19 [1]	13	17
BEEF PRODUCTION	6	5 [2]	5	8

Chart 1

"Comparative Proteins" by Dr. Damon V. Catron, University of Missouri (1967)

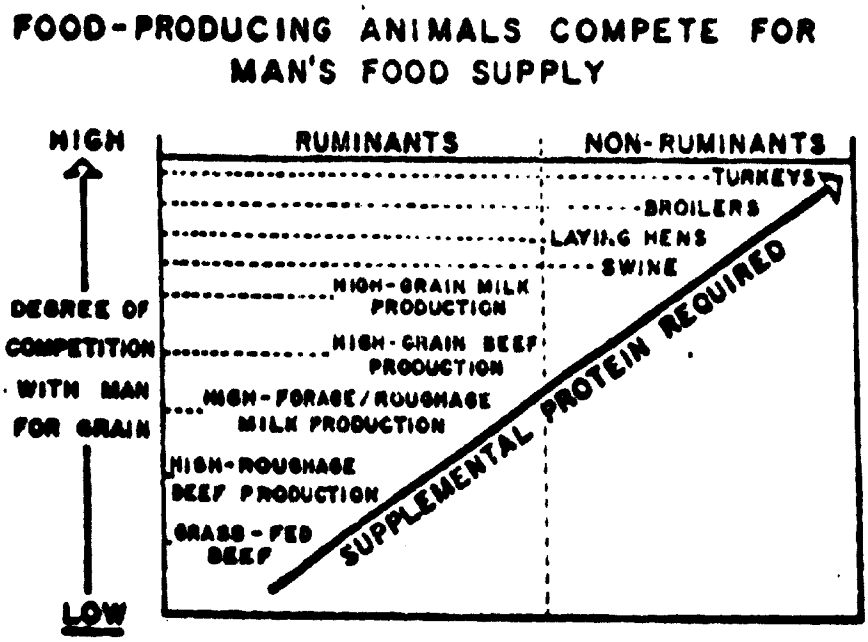


Chart 2

"Comparative Proteins" by Dr. Damon V. Catron, University of Missouri (1967)

CHART 3

SOYBEAN PROCESSING

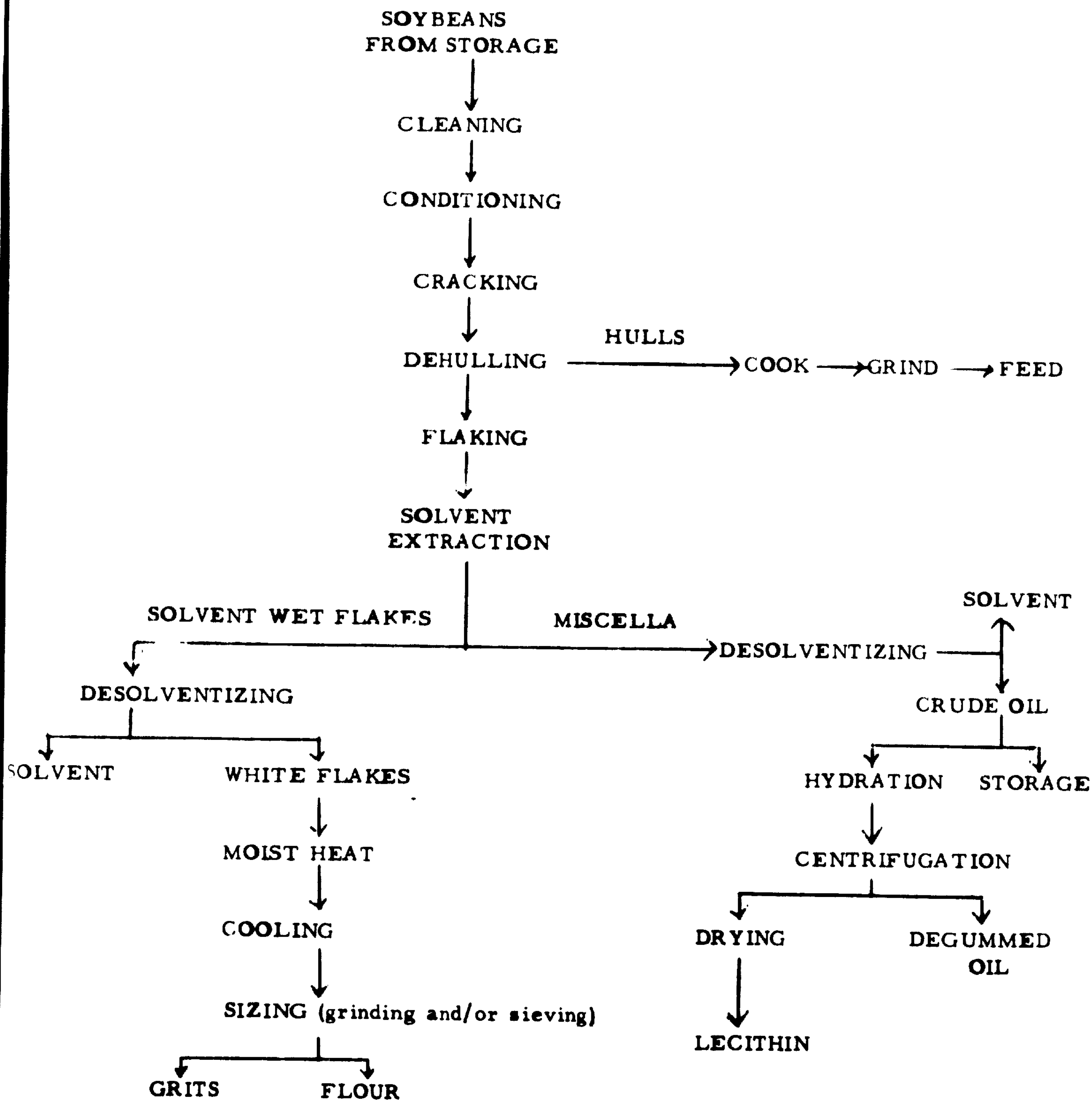
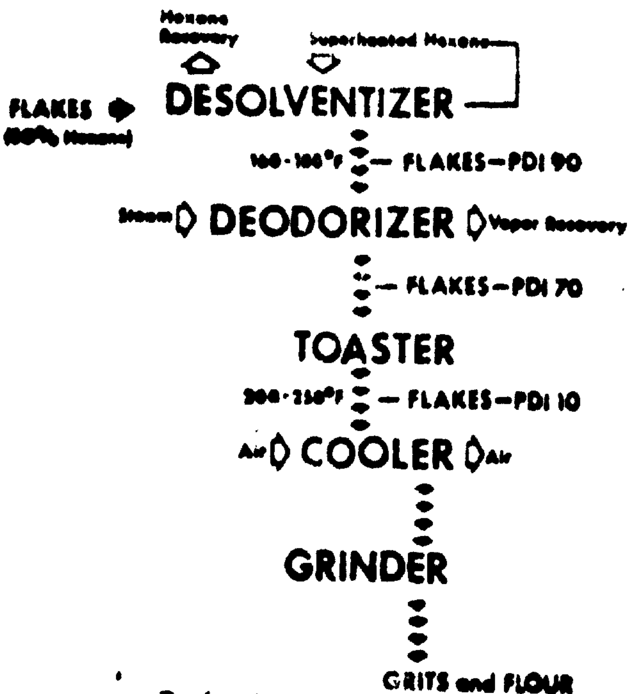


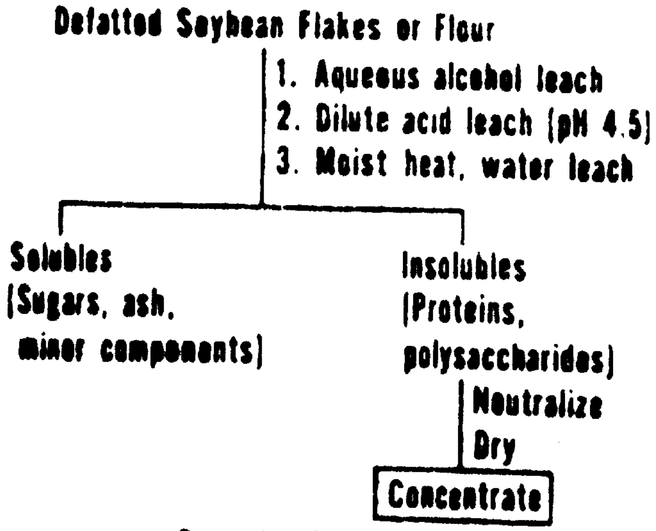
CHART 4



Desolventizer-deodorizer-toaster system.

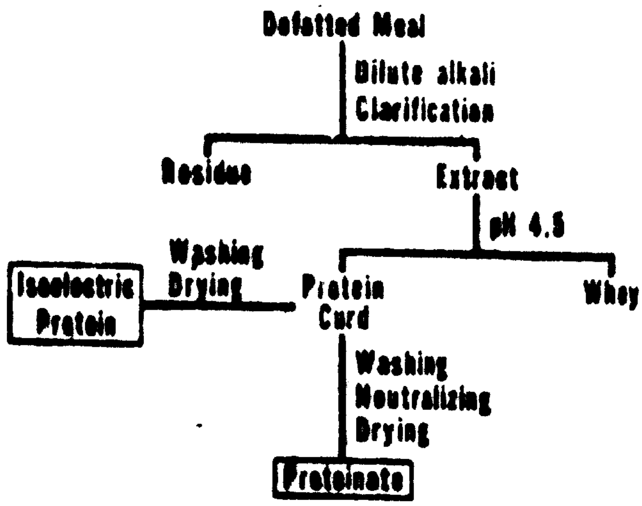
HORAN - JAOCS-51, 67A, 1974

CHART 5



Preparation of soy protein concentrate.

Commercial Isolation of Soybean Proteins



Process for the preparation of isolates soybean protein.

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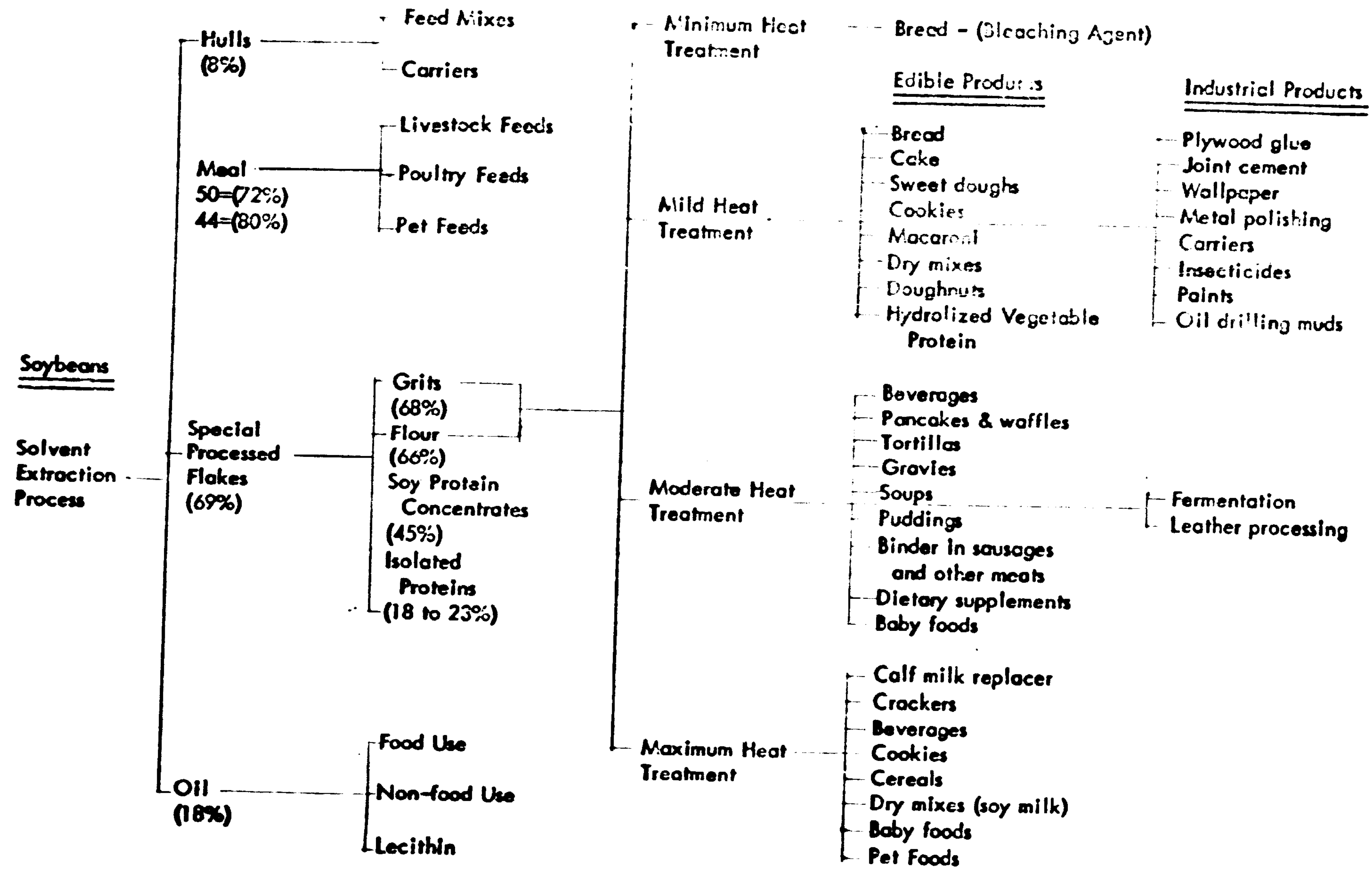
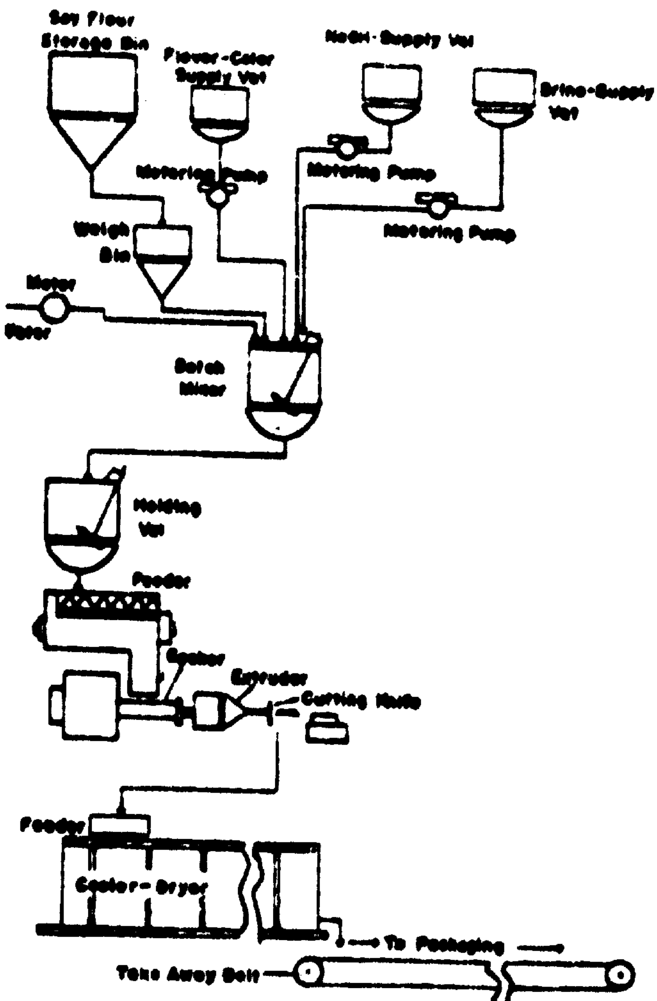
PRODUCTS FROM THE SOYBEAN AND USES



• Figures in ( ) indicate typical yield from soybeans

CHART 6

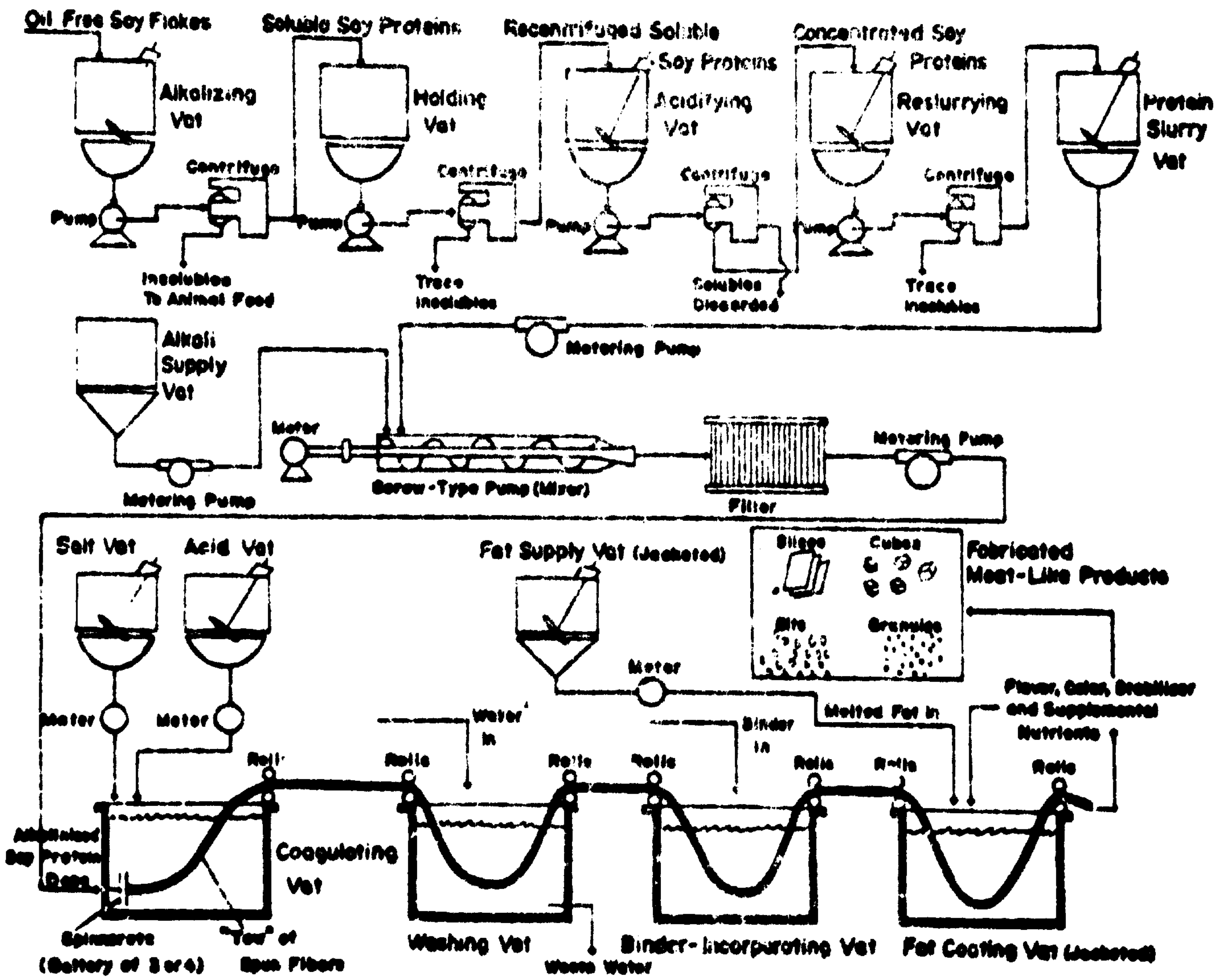
CHART 7



Thermoplastic extrusion process. Cooking extrusion is a technique for texturizing soy flours. Technique is similar to that employed for manufacturing cereal based snack foods.

HORAN - JAOCS-51, 67A, 1974

CHART 8



Soy protein spinning process.

HORAN - JAOCS-51, 67A, 1974

74.10.1