Processing of Oilseeds to Meal and Protein Flakes[1]

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ABSTRACT

The prime consideration during processing of oilseeds to meals and flakes, i.e. toasting or cooking, is the time-temperature-moisture content relationship. Protein dispersibility decreases during the processing steps with an increase of any of these variables, but there is a threshold value for each variable below which the denaturation rate is very slow. In general, denaturation of protein is measured by its water dispersibility, i.e., denaturation increases as protein water solubility decreases. Choice of the extraction process for oilseeds depends primarily on the oil content of the seed and the allowable protein denaturation during preparation for extraction. Seeds with oil contents up to 30% may be extracted directly in percolation extractors, with minimum protein denaturation. Higher oil content seeds must be prepressed with some denaturation or they can be extracted by an immersion process such as centrifuge battery to minimize protein denaturation. The desolventizing operation is the most critical in fixing the degree of protein denaturation, since all three pertinent variables are near or above their threshold values. The selection of the proper processing units to desolventize completely the meal but maintain desired limits will be discussed. Subsequent heat treatment after the desolventizing process may be used to denature the protein or may be minimized to prevent much further denaturation. Prompt cooling is necessary before storage to preserve the required protein denaturation values. Classification and sizing may be required to meet the meal specifications.

INTRODUCTION

Recently, many domestic and foreign oilseed processors have completed expensive modernization programs for more efficient production and marketing facilities. These new facilities are mostly oriented to the production and marketing of conventional products, meal for animal food and vegetable oil for humans. As we approach the next decade, the oilseeds companies are at the threshold of a new era of more sophisticated production techniques and marketing practices than had existed previously. Technological changes in this industry will force more drastic production alterations and management reorganizations in the 1970's than have occurred in any earlier similar period. This, of course, leads up to the questions, why? and what can we do about it?

Consider the trends which are already apparent that will affect the competitive nature of the oilseeds industry. One such trend is the large soybean manufacturing complex which processes 2000 tons or more per day of soybeans to produce a multiplicity of both animal and human food products. These plants not only have the advantage of much lower operating costs than smaller plants but also have captive markets for their meal and vegetable oil products. For these soybean complexes, we must expect increased product diversification that may include not only the following but other products not yet developed or marketed in the U.S.A.: vegetable oil products–degummed oils, refined oils, salad and cooking oils, margarines, shortening stocks and monoglycerides; conventional meal products–ruminant feeds, poultry feeds and swine and other animal feeds; protein products from meal–industrial isolates, simulated meat products, meat extenders, supplements for baking goods and cereals, snack foods, milk products and milk additives, soy flour, protein 70 and food isolates.

Another trend is the published commitment by major petroleum companies such as British Petroleum, Esso, Mobil, Gulf, Chevron Oil, American Oil and others to produce petro-proteins. Substantial funds are being expended to develop several processes first for animal and later for human food. Already, semicommercial plants are being built in France, Scotland, Japan and California (1). No doubt a number of U.S.A. petro-protein plants will be built during the next several years. These plants will have the following inherent advantages: high yield of 65-70% protein product, simplicity of process as compared to other petroleum processes and the oilseeds protein processes, ability to produce protein several thousand times faster than naturally occurring protein, least profitable fraction of petroleum utilized and production feasible in areas not economically suitable for oilseeds. While technical, economic and sociological problems have to be overcome before petro-proteins become widely accepted and used, there is little doubt that these problems will be overcome and that these products will compete with oilseeds meal products for markets in the next decade.

In addition, we can expect the worldwide trend toward alleviation of protein deficiency in both the underdeveloped and developed countries to continue. Fish protein concentrate, algae, high protein corn and additional protein from poultry and animal sources will supply only a portion of the increased demand. The opportunity exists now for oilseeds processors to find an economical means to supplement mankind's diet through increased and better use of oilseeds proteins. Otherwise, in another generation mankind must depend mainly on petro-proteins to supplement his diet.

What can an oilseeds processor, small or large, do to prepare for the technological and marketing revolution brought about by changing conditions? Obviously, it will be necessary to participate in the growing protein market either as a supplier to protein processing plants or as a manufacturer of protein products. Since new expansion and debottlenecking programs are constantly being planned and executed by the oilseeds industry, it is desirable to carry out this work in such a manner as to achieve future goals in the protein field.

Figure 1 illustrates a flow chart of a soybean solvent extraction plant. In this paper, pertinent ground rules are presented for processing soybeans to meal so that conditions will be optimized for protein products. Discussion is confined mainly to soybeans since most oilseeds protein products are produced from that source. Production of cottonseed protein products is still in the developmental stage and is awaiting widespread use of glandless seed or a proven economically feasible process for effectively removing gossypol.

A prime consideration during the various processing steps of oilseeds to meals with respect to protein denatura-

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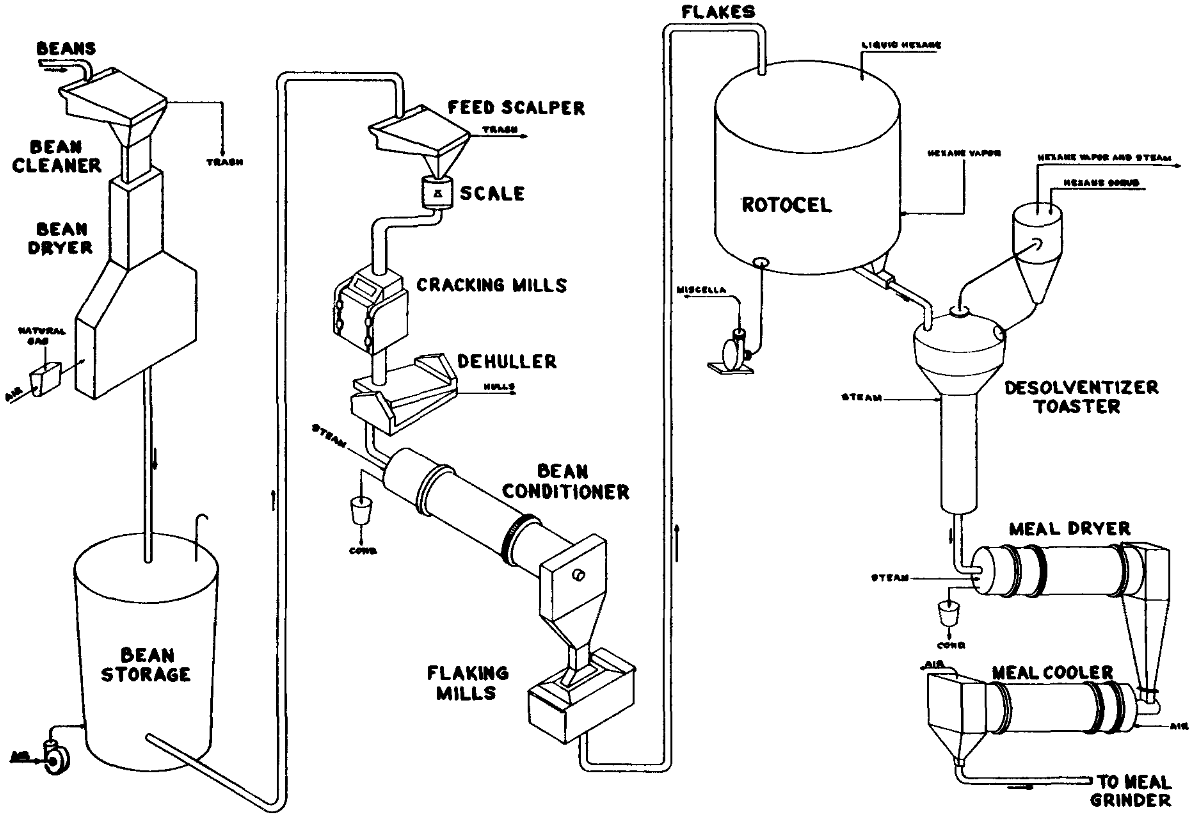

FIG. 1. Flow chart of soybean solvent extraction plant.

tion (i.e. cooking) is the time-temperature-moisture relationship. Protein denaturation rate increases with an increase of any individual variable. However, there is a threshold value for each variable below which the denaturation rate is very slow. In general, denaturation of protein is measured by its water dispersibility; i.e., water dispersibility decreases as denaturation proceeds. Protein denaturation is most likely to occur as a result of inadequate care taken during drying and storage, or during the processing steps of conditioning and flaking, desolventizing, drying and cooling.

RAW MATERIAL SELECTION AND CLEANING

Raw materials should be selected which can be processed to meet the specifications for protein and products. Obviously, raw materials containing toxic materials or foreign matter which is difficult-to-remove are not acceptable. Likewise, sprouted, immature, heat-damaged or physically damaged seeds or beans generally will be unsatisfactory because these materials deteriorate rapidly.

Most of the dust, chaff, rocks, scrap iron, wood, etc., should be removed by aeration and screening before drying and storage. It is desirable to clean soybeans and remove plant stems, foliage and other trash before the beans are stored because this material decomposes rapidly, heats and causes soybean deterioration. Consequently, it has been suggested that trading rules be revised so that penalties start above trace levels of foreign material rather than 1%. With present trading rules, farmers and country elevators have an incentive to add enough dirt and trash to bring up the allowable foreign material to the maximum. It would become very expensive, and often would be impractical, to remove every type of foreign matter prior to processing soybeans for certain protein products. For raw materials used to produce soybean isolates and concentrates, it is essential to remove foreign matter very carefully so that the protein products will not be contaminated by color bodies.

DRYING AND STORAGE

Moisture is generally believed to be the most important factor in promoting the deterioration of stored grains. Acceptable maximum storage moisture level is about 13% for soybeans. During the past 20 years, drying of beans before storage has become standard practice in most plants, thereby minimizing difficulties in processing any high moisture crop. Various soybean dryers are available to handle either high throughput and small moisture reduction or low throughput and high moisture reduction.

Properly dried and stored raw materials will process considerably better through a solvent extraction plant than materials which have been allowed to deteriorate. For example, improperly dried soybeans are difficult to dehull and solvent extract. Many processors frequently lose considerable efficiency because drying facilities are inadequate (2).

Raw material storage represents one of the largest capital investments in an oil mill. Storage should be designed to permit segregation of grain by good and poor quality, control of moisture level and control of temperature. Ample use of cooling fans, temperature recorders for grain in bins and conveying facilities for "turning over" the grain should be made to prevent deterioration due to local overheating and high moisture. It should be remembered that there is seasonal movement of moisture within a storage unit even where the average moisture content is low enough for safe storage. For example, during the fall and winter, soybeans near the walls and upper surfaces cool more rapidly than those near the center of the bin. As a result of convection air currents created by the temperature differential within the bin, condensation occurs as the warm moist air reaches the cool upper layers of beans. Tests reveal that beans with a uniform moisture content of 12%,

TABLE I

Typical Nutritional Values of Soy Flours

Type	Protein dispersible index[a]	Relative protein efficiency[b]
Negligible heat	90-95	40-50
Light heat	70-80	50-60
Moderate heat	35-45	75-80
Toasted	8-20	85-90

[a]As measured by AOCS Tentative Method Ba 10-65.

[b]Dried skim milk equals 100%.

when stored in early autumn, have reached moisture contents of 15% to 19% in the upper layers during mid-winter.

CRACKING AND DEHULLING

Soybeans are normally cracked into six or eight parts prior to dehulling. Good cracking at uniform conditions facilitates good dehulling, flaking and extraction, and contributes to the conditions which permit production of meal suitable for subsequent processing into protein products.

Soybeans are approximately 93% kernel and 7% hulls. The whole seed contains about 18% oil and the hulls contain about 0.6% oil. Many United States plants have already installed dehulling equipment for the purpose of producing high protein, low fiber meal which is commonly known as 50% protein meal. The fiber content of such meal should be less than 3% and the oil content in separated hulls will be about 1.5%. The hulls will be blended back with 44% protein meal or sold as low grade meal for blending. Recently, soybeans, under favorable growing conditions, have tended to average about 38% protein. Since the extracted and desolventized meal from such soybeans will then contain 46% protein even without dehulling, the oil mill processor can blend back purchased low cost hulls to produce additional 44% protein meal for animals.

CONDITIONING AND FLAKING

Soybeans are conditioned prior to flaking so that moisture and temperature are at optimum conditions. Normally, moisture is adjusted to 10-11% and temperature is raised to about 160 F during conditioning. Proper conditioning yields bean pieces which are sufficiently plastic that good flakes can be formed.

TABLE II

Typical Uses of Soy Flours

Product Type	Industry use
PDI 90-95	Bleaching agent in white bread
PDI 70-80	Bakery mix Doughnut mix Beverage Hydrolyzed vegetable protein Baby cereals
PDI 35-45	Pharmaceutical Baby cereals Meat processing Beverages HVP Bakery Pet foods Animal milk replacers
PDI 8-20	Pharmaceutical Baby cereals Bakery Meat processing Pet foods Animal milk replacers

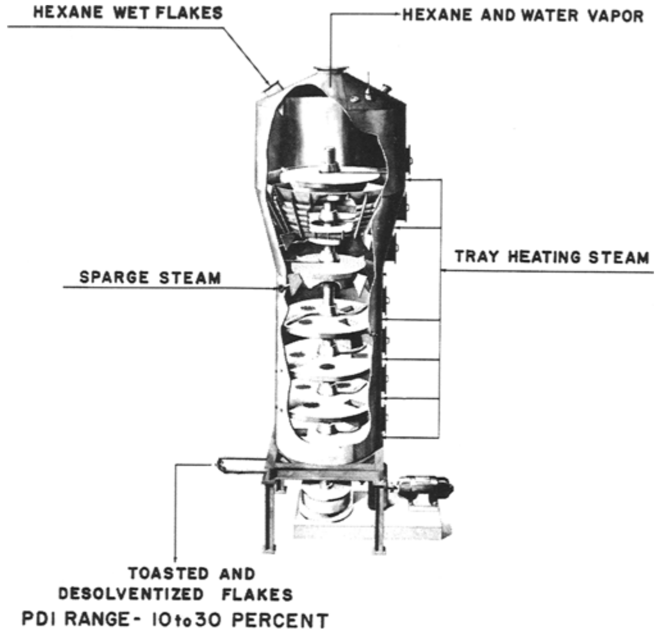

FIG. 2. Desolventizer toaster system.

Properly prepared flakes are essential for consistently good extraction. Normally, soybeans are flaked to 0.010 to 0.012 in. thickness before extraction. However, for certain Oriental foods or for improperly tempered and dried beans, it is necessary to prepare much thicker flakes. These thicker flakes extract more slowly and take longer to desolventize.

One importnat point to remember is that deterioration takes place more rapidly after flaking because a relatively large surface is then presented to the air for possible oxidation and hydrolysis after the cells have been ruptured. Consequently, interruptions in operation are more likely to yield poor quality meal.

SOLVENT EXTRACTION

In general, conditioned soybean flakes are extracted with hexane in a percolation type extractor to produce oil and meal of the greatest possible value consistent with marketing conditions. Most soybean solvent plants are designed to extract flakes to 0.5% residual oil on untoasted flakes (AOCS Method Ac 3-44). In conventional practice, extraction plants frequently operate considerably in excess of design capacity, thereby producing meal with higher residual oil content (3,4).

Clean, good quality soybean flakes should be extracted to a uniform residual oil content (0.5 to 1.0% on flakes) before subsequent separation of the protein fractions. This will not only avoid contamination problems but will enhance standardization of protein functional properties.

The extracted flakes used to produce protein isolates should contain less than 1.0% residual oil since excessive oil will tend to remain with the protein fraction and cause emulsification problems. Higher oil content in the flakes may also cause the product edible protein to become slightly rancid. For industrial proteins, particularly those used in paper coating applications, any excessive amount of oil in the extracted flakes may separate from the protein into undesirable "fish eyes."

For other oilseeds, choice of the extraction process depends primarily on the oil content of the seed and the allowable protein denaturation during preparation for extraction. Seeds with oil content up to 30% may be direct extracted in percolation extractors with minimum protein

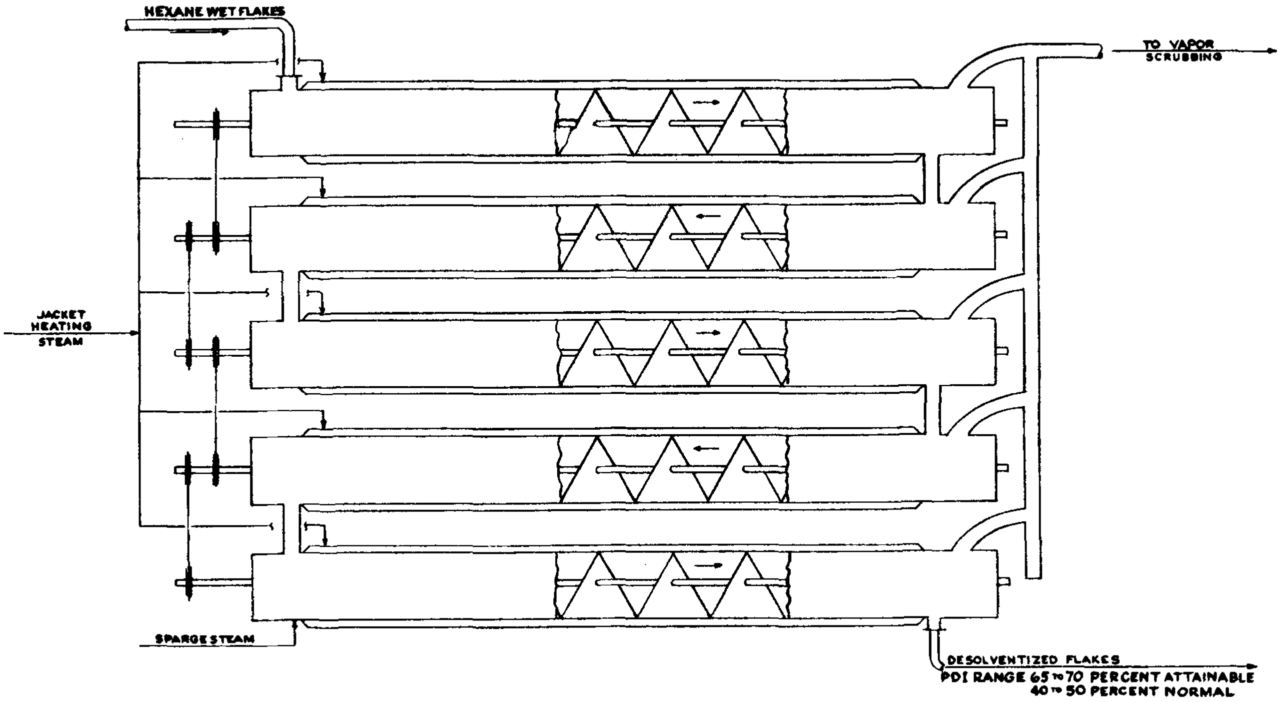

FIG. 3. Schnecken system.

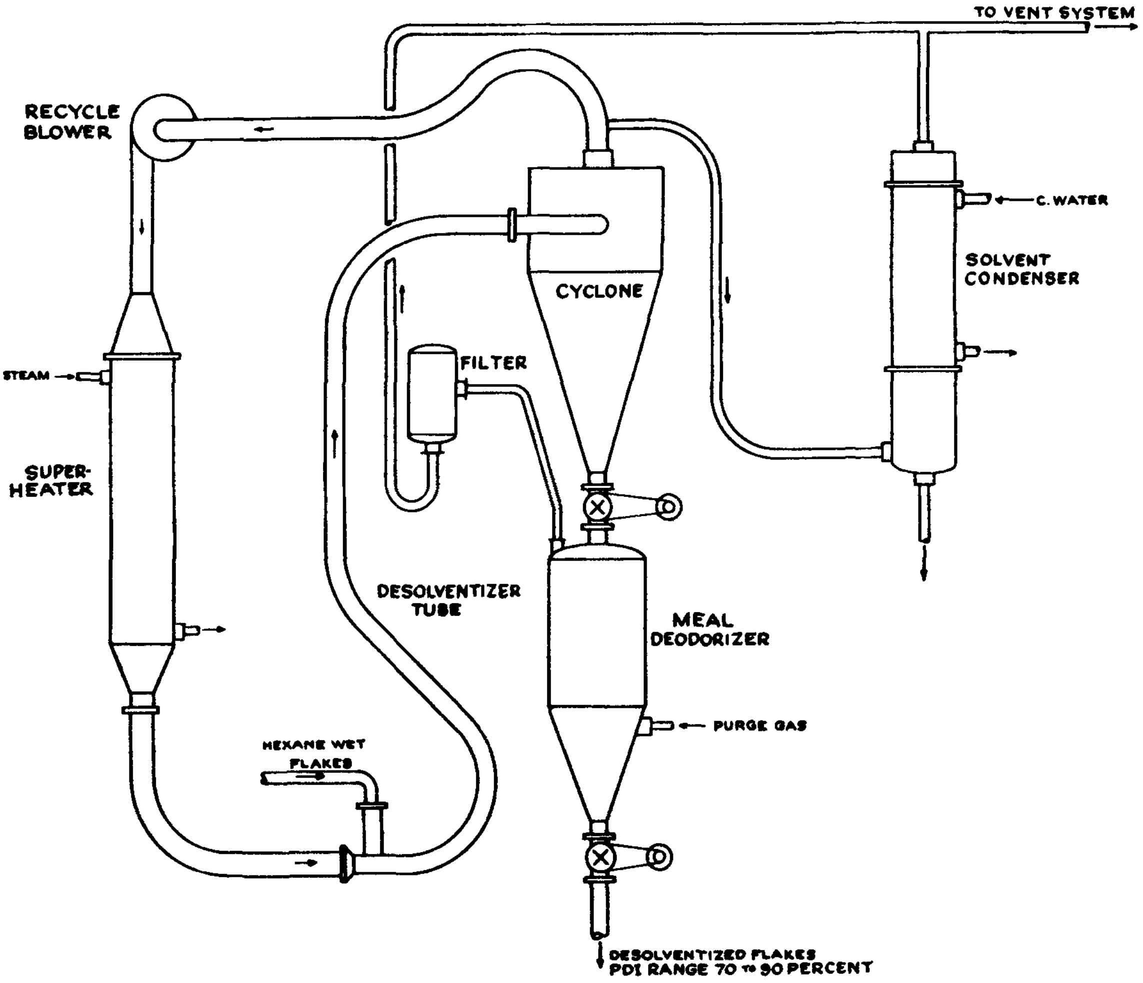

FIG. 4. Flash desolventizer system, U.S. Patent 3,367,034.

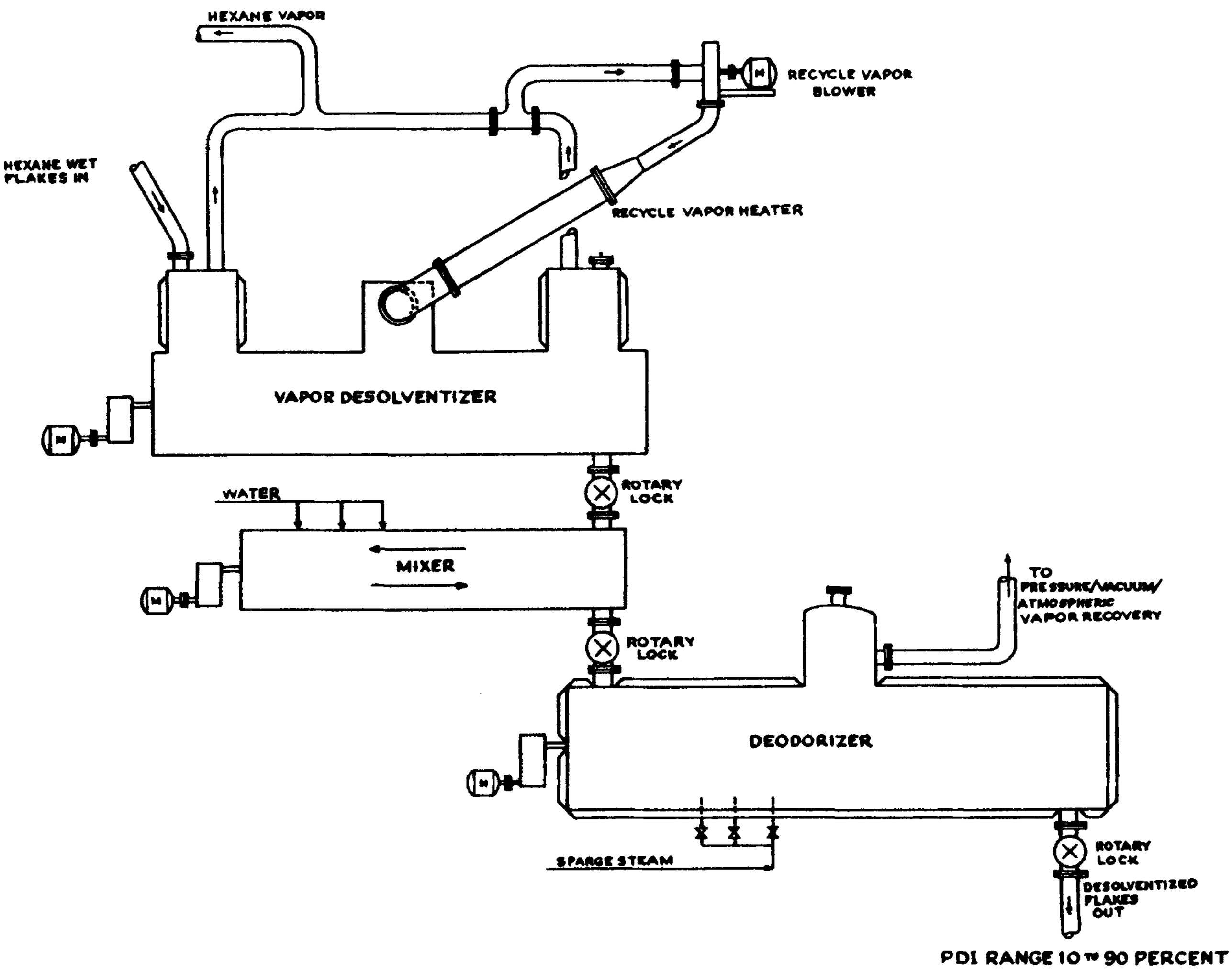

FIG. 5. Vapor desolventizer deodorizer system, U.S. Patent 3,392,455.

denaturation. Higher oil content seeds must be prepressed with some denaturation or they can be extracted by an immersion process such as centrifuge battery to minimize protein denaturation.

DESOLVENTIZING

To produce a soybean product having both the required protein dispersible index (PDI) and relative protein efficiency, control of processing procedures in desolventizing is essential. All three pertinent variables (time, temperature and moisture) are near or above their threshold values during desolventizing.

Soybean protein has excellent nutritive value when it is properly processed. Typical commercial defatted soy flours and their relative nutritional values are summarized in Table I (5).

Typical uses of soy flours with varying degrees of protein denaturization as measured by PDI value are presented in Table II.

All types of desolventizing systems must be designed to receive extracted soybean flakes containing about 30 wt % hexane and remove the hexane from the meal down to commercially acceptable levels. Four typical types of desolventizing systems are described. The selection of the proper type of desolventizing system is governed by the variety and type of meal products to be marketed. Figure 2 illustrates a desolventizer toaster system (6). It is a vertical vessel containing steam heated tray sections. Hexane wet flakes which enter the top section are sparged with steam on one of the upper trays. Steam condenses in the flakes vaporizing the hexane so that the moisture content of the flakes is raised to about 20%. In the lower tray sections, flakes are heated to about 225 F and the moisture content of the flakes is reduced several per cent. The desolventizer-toaster is commonly used to produce toasted meal for ruminant and poultry feeds. Typical PDI products range from 10 to 30%.

Figure 3 illustrates a Schnecken system. These units are horizontally mounted steam-jacketed conveyors which are arranged one above the other in banks. Solvent wet meal enters the top and is desolventized by jacket heat until it reaches the bottom units. Then sparge steam is introduced to finish removing the solvent.

Experience with Schnecken indicates they are difficult and hazardous to clean, expensive to maintain and generally do not remove solvent as thoroughly as other types of desolventizing systems. The maximum attainable PDI on meal product is in the range of 65% to 70%, with normal PDI values in the range of 40 to 50%.

Figure 4 illustrates a flash desolventizer system which includes both desolventizing and meal deodorizing sections (7). The desolventizer section consists essentially of a pneumatic (hexane vapor) conveying tube into which solvent extracted flakes are fed and through which superheated solvent vapors simultaneously desolventize and convey the flakes to a cyclone separator. The vapors and flakes are separated in the cyclone. The solvent removed from the meal flows to a condenser and the balance of the hexane vapor is recirculated through the superheater.

Desolventized flakes with most of the solvent removed are discharged through a rotary lock to the meal deodorizer.

In the meal deodorizer, the balance of the solvent is stripped from the flakes by an inert purge gas which flows counter to the meal. The purge gas can be recycled through a filter and a hexane condenser, and reused again.

The attainable PDI on meal product is in the 70 to 90% range with the upper limit approaching a reduction of only 1 or 2% below the PDI value of the solvent-wet flakes.

Figure 5 illustrates the vapor desolventizer-deodorizer system which produces the widest variety of products as measured by PDI values (8). All three pertinent variables, i.e., time, temperature and moisture, are adjusted at will during operation.

About 99% of the solvent is removed in the horizontal vapor desolventizer. A special cage conveys and showers the flakes through superheated solvent vapor. Residence time is only 3 or 4 min, temperature of the flakes is kept under 185 F, and no moisture is added. In fact, there is a slight moisture reduction while passing through the recycle vapor desolventizer. PDI value of meal from the recycle vapor desolventizer is essentially that of solvent wet flake feed. Should maximum protein denaturation be required in the product meal (low PDI values) water is added to the vapor desolventizer product meal in the mixer conveyor ahead of the deodorizer.

The deodorizer is a horizontal vessel containing a conveying and lifting device, designed to provide intimate contact between flakes and stripping gas (steam). The vessel is provided with a discharge dam arranged so that retention time can be adjusted during operation by regulating meal level. Pressure within the vessel can be regulated as required between 1/2 atmosphere and 2 atmospheres. Under vacuum (1/2 atmosphere), steam does not condense in the meal and acts as a solvent stripping medium. At atmospheric pressure some steam condenses in the meal while vaporizing hexane but the balance of steam acts as stripping medium. As pressure increases, more of the steam condenses while vaporizing hexane and now the moisture is high enough for a thorough cooking operation. It will be found that primary control of PDI value of product meal is attained in the deodorizer and mixer by controlling the following: residence time—meal level in the unit controlled by the movable dam; temperature—set by vacuum, atmospheric or pressure operation; moisture—set by stripping steam flow and pressure control in the deodorizer to control quality of condensed steam in the meal. Further moisture addition, if required, is accomplished in the mixing conveyor.

The advantages of the Blaw-Knox vapor desolventizer-deodorizer system are low steam consumption, control of time, temperature, moisture as required to produce desired PDI products, trouble-free operation and low maintenance, high recovery of solvent and minimum flake breakage for Japanese protein products.

Product meal PDI values can be controlled throughout the range of 10 to 90% with the upper limit approaching 1 or 2% below the PDI of the extracted soy flakes.

MEAL DRYING, COOLING AND STORAGE

From a desolventizer-toaster system, the meal is dried first in a rotary steam tube dryer and is then cooled by air before being sent to storage.

Meal from Schnecken, flash dryer and vapor desolventizer-deodorizer systems does not need to be dried. Hence, when calculating capital and operating expenditure for such systems, credit should be taken for the elimination of the conventional meal dryer.

Typically, the desolventized meal will be stored at 12% or less moisture and about 100 F maximum temperature. However, occasional upset operations or equipment malfunctions will cause higher temperature and/or higher moisture meal than typical to be produced. In storage, these abnormally produced meals are subject to further denaturation, as well as difficulties in removing meal from bins.

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