Processing

Oilseeds:
Extrusion for solvent extraction

The following article on extrusion enhancement of oilseeds for solvent extraction was prepared by E.W. Lusas and L.R. Watkins of the Food Protein Research and Development Center at Texas A&M University, College Station, Texas. Serving as Associate Editors for JAOCS *News for Processing for this article were Reginald Bacchus of the POS Pilot Plant Corp. and Larry Johnson of Iowa State University.*

The extrusion of oilseeds before solvent extraction has been one of the least talked about changes in the edible oilseeds industry in the last decade. The first known domestic use occurred in 1976, when a Technal Expander was imported from Brazil for processing cottonseed in a direct solvent extraction plant in Texas. It is estimated that approximately 60% of the current domestic soybean crush and 50% of the cottonseed crush are now processed with expanders.

Advantages claimed for extrusion of oilseeds include: increased recovery of oil; increased capacity (doubling in some cases) of solvent extractors because of higher density of extruded collets compared to flakes (38 lbs/ft^3 and 25 lbs/ft^3, respectively); improved percolation of the extraction bed, because the collets are not as fragile as flakes and the freed oil is more readily accessible to the solvent; better drainage of solvent in the extractor bed (less hexane hold-up), resulting in more effective "washing" in a typical six-stage countercurrent solvent extractor and lower energy requirements to recover solvent from the marc; opportunities to deactivate undesirable enzymes such as lipase in rice bran, and phospholipase in soybeans and other oilseeds where development of non-hydratable gums sometimes presents problems; opportunities for conducting other chemical reactions while processing oilseeds; and opportunities to put the expander to other uses, such as producing chunk-style dry pet foods and medium-fat content animal feeds during periods when the extraction plant is idle.

Uses of expanders described in the literature include deactivating lipases in rice bran and enhancing its extraction (1), and processing of cottonseed and soybeans (2,3) and experimental high-oil content corn (4). Use of a low-cost "dry-extruder" to enhance mechanical expelling of soybean oil in small screw-press plants, particularly in developing countries, has also been reported (5). An application for a process patent, to stabilize rice bran by extrusion, was filed in 1962 and a U.S. patent issued in 1966 (6). Reportedly, domestically manufactured extruders were sold for processing rice bran to Brazil in 1965, Ecuador in 1969 and Mexico in 1970. Techniques for extrusion-processing of soybeans were developed in Brazil and returned to the U.S. in the late 1970s.

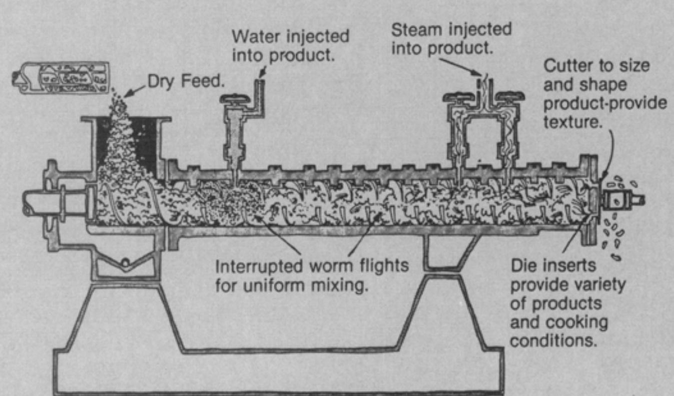

FIG. 1. Cross-section drawing of a cut-flight screw expander (Courtesy of Anderson International Co.).

Equipment

As used in the oilseed milling industry, the terms "extrusion" and "expander processing" are synonymous, with the word "expander" a generic reference to a machine first built by the Anderson International Co., Cleveland, Ohio, and known as the Anderson International Grain Expander. This machine has a cut-flight screw, with bolts protruding from the barrel into the spaces between the discontinuous flights to add shear to the product. A cut-away drawing of this type of machine is shown in Figure 1. The expander generates considerable autogenous heat, but can have two or more jackets for contact heating with steam, as well as options for direct steam injection through one or more of the ports obtained by replacing a shear bolt with a steam injection valve. As in typical extrusion practice, it is sometimes desirable to cool the jacket section closest to the feed end to prevent blow-back of steam. The processed oilseed is heated well beyond the boiling point of water, and results in "puffing" or expansion after leaving the die. Cutting of the extruded rope into even-size pieces or "collets" is often bypassed in favor of the natural breaking action that occurs as the product is transported to the solvent extractor by screw conveyors.

Extruders of this general design include the Grain Expander available from Anderson International Co., Cleveland, Ohio, and

W.C. Cantrell Co., Ft. Worth, Texas; the Enhanser made by French Oil Machinery Co., Piqua, Ohio; the Picard Expander made in Des Moines, Iowa; and the imported Technal Expander sold by William Hendrick Consultants, Ft. Worth, Texas, and by H.L. Moore Associates, Memphis, Tennessee. Also, machines of this type have been built on special order by various screw-press refurbishing shops. Differences exist in screw and barrel designs that, although apparently subtle on first sight, may require different operating conditions with various crops.

Capacities of extruders for expanding oilseeds are four to seven times greater than when the same configuration and motor horsepower are used for extruding pet foods. A typical manufacturer's rating for an eight-inch (barrel diameter) expander is 275 tons per day (TPD) on cottonseed, and 500 to 800 TPD for a 10-inch machine.

FIG. 2. Extruded dehulled soybean collets (left), same collets after solvent extraction (right).

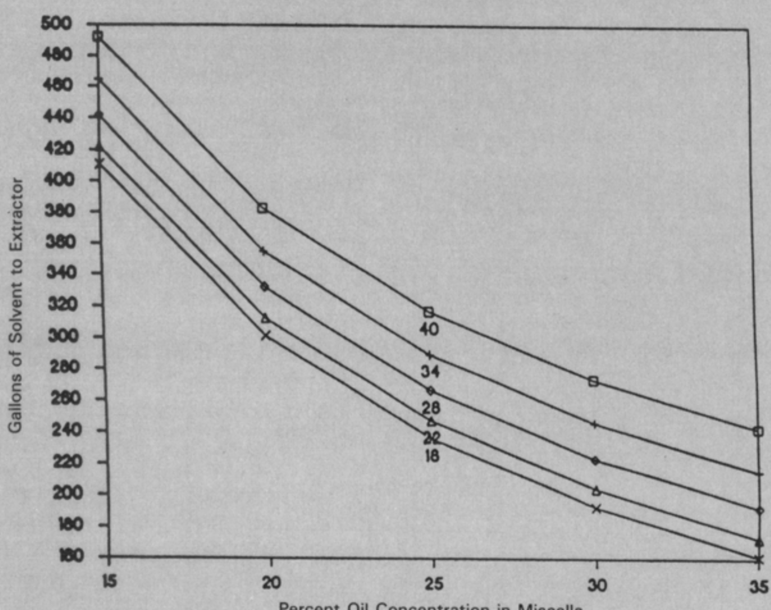

FIG. 3. Relationships between hexane requirements per ton of cottonseed processed, oil concentration in the miscella and hold-up of solvent in the marc, direct-solvent extraction process.

Operations

Extrusion of oilseeds for solvent extraction is better characterized as a dry rendering process rather than a cooking operation. The objective is to heat the seed to denature the protein and make the cell walls and contents sufficiently brittle so that oil will be freed from the sphereosomes by the shearing action. On discharge to the atmosphere, the oil "boils" to the surface with the steam. The resulting chunks have an oily, amorphous, sintered appearance rather than the cell structure characteristic of extruded starch products and grains, or the laminar appearance of texturized soy protein. A photograph of extruded and solvent-extracted collets is shown in Figure 2.

Seed is typically dehulled, conditioned and flaked before expansion to raise its temperature and initially rupture some of the cells. Optimum operating conditions, including moisture level, temperature and retention time, differ between crops, although general guidelines are 10% to 15% moisture and a final product temperature of 220–250° F.

Extrusion moisture content recommendations of 18%–25% have been reported (2,6) but would require dryers to significantly reduce moisture content before extraction. In practice, it is possible to achieve good release of oil by expanding at lower moisture levels, although opinions differ about the optimum levels for various oilseeds. Up to 5% moisture can be flashed off when the processed seed leaves the expander die, and further moisture loss occurs during cooling of the collets to less than 140° F before extracting with hexane. Long cooling lines, or supplementary dryers, may be required to reduce the moisture content of the collets to less than 9% for optimum solvent extraction. A controller to maximize expander throughput, by direct injection of steam as the motor load increases, is offered by Brandon and Clark of Lubbock, Texas.

A source of non-denatured protein and/or a low level of starch is necessary to hold the extruded chunks together, although a high level of starch will adsorb the oil. A wide degree of protein denaturation, estimated by the Protein Dispersibility Index (PDI), can be achieved during extrusion. Good oil recoveries (less than 0.5% residual oil in the meal) can be achieved from extruded soybeans with PDI of 65 or higher in the non-toasted meal. Although oilseeds typically are exposed to higher temperatures in extrusion processing, the treatment time is much shorter and the moisture content often lower than in traditional processing. Oil millers, who replace operations such as "cooking" of cottonseed to produce low-gossypol content meal with extruders, are advised to check on the free gossypol content of the product because the initial extrusion process may be less effective at binding gossypol than the former cooking process. Good extraction can be realized from expanded soybean collets, which require additional heat treatment in the desolventizer-toaster (DT) to inactivate urease and reduce trypsin inhibitor levels.

Because of higher shear, temperature and moisture conditions in the expander and the resulting seed cell disruption, larger quantities of phospholipids are extracted from extruded oilseeds. The presence of these compounds will place heavier demands on subsequent degumming operations. However, by arranging for sufficient time to hold the collets hot between extrusion and extraction, non-hydratable phosphatide contents in the oil after degumming can be significantly reduced from those of traditional operations to obtain results similar to the Alcon Process.

One of the authors has seen several commercial soybean operations in which introduction of an expander into a direct-solvent extraction plant resulted in reduced hexane hold-up in the marc from 33% to 20%; reduced residual oil in dried meal from 1.0% to 0.5%; reduced residual oil in the white flakes from 0.6% to 0.4%; increased gums in the crude oil from 2% to 3.5%; and reduced moisture in the meal at the DT discharge from 17% to 13.5%, with elimination of steam required at the dryer.

The Food Protein Research and Development Center has developed successful processes for deactivation of aflatoxin in peanut meal and for detoxification and deallergenation of castorseed meal using extruders as continuous reactors. These applications are overseas and have not been described in publications. The Anderson International Grain Expander has been used for extrusion of dry pet foods for many years, and the center also has unpublished data on use of this machine for making 18%–20% fat content pellets for dairy feed.

Savings

The savings to a soybean or cottonseed oil mill that installs an expander accrue from higher solvent

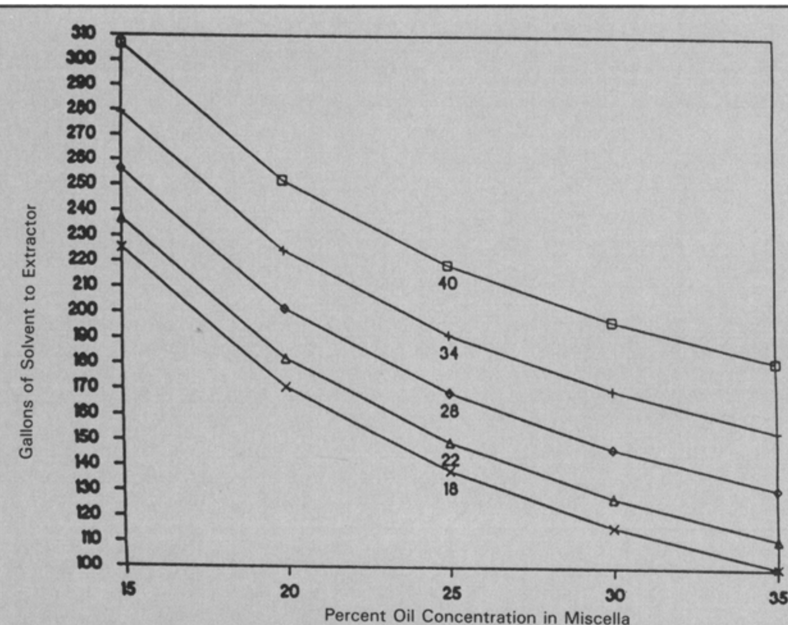

FIG. 4. Relationships between hexane requirements per ton of cottonseed processed, oil concentration in the miscella and hold-up of solvent in the marc, prepress-solvent extraction process.

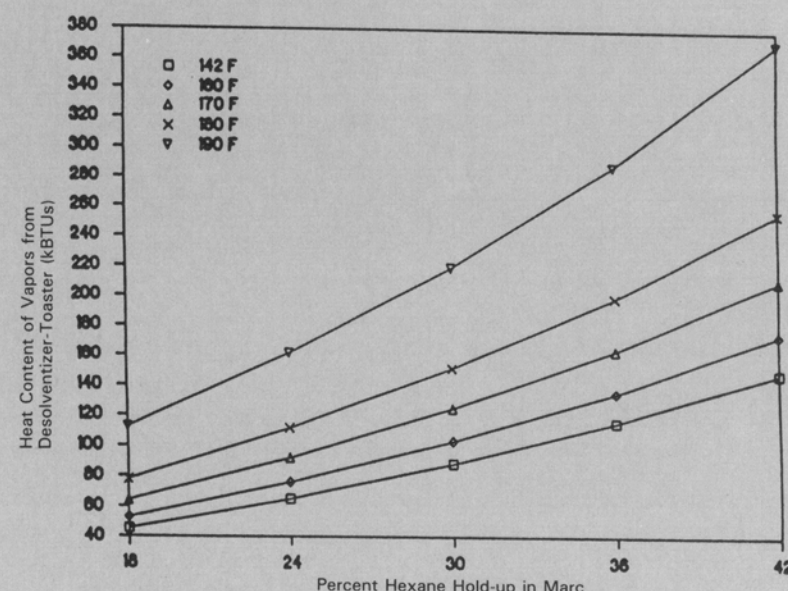

FIG. 5. Relationships between heat content of desolventizer vapors per ton of cottonseed processed, hexane hold-up in the marc and temperatures of vapors, direct-solvent extraction process.

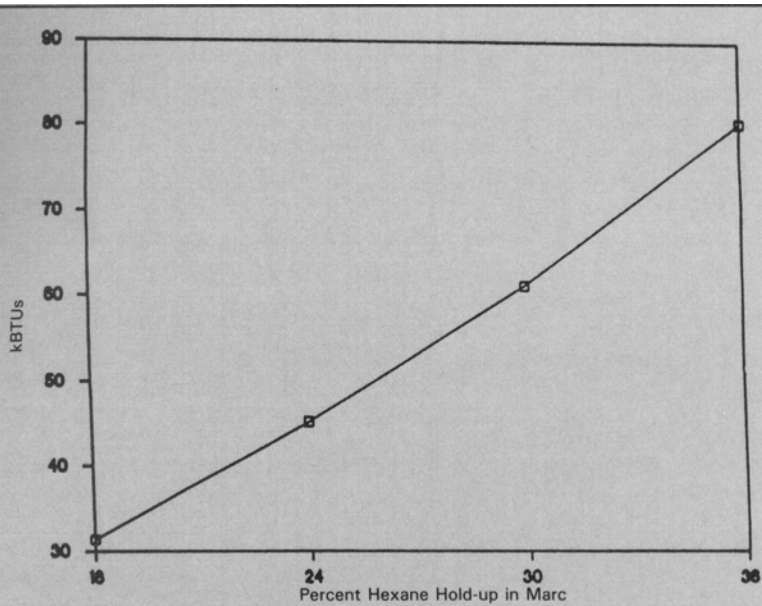

FIG. 6. Relationships between energy requirements to dry desolventized meal to 10% moisture level per ton of cottonseed processed and hexane hold-up in the marc, direct-solvent extraction process.

extractor throughput; higher concentrations of oil in the miscella, with reduced concentration costs for subsequent miscella refining or degumming; reduced energy costs to dry desolventized meal; and refined capital, maintenance and energy costs when the expander replaces an expeller in a prepress-solvent extraction plant.

The response curves are of the same general trend but differ between oilseeds. This report presents data for cottonseed because both prepress-solvent extraction and direct-solvent extraction are used for this crop, and the information may be of interest to persons processing crops such as canola and sunflowerseed, where prepress-solvent extraction also is used. Figure 3 shows relationships between solvent hold-up in the marc, the percentage of oil obtained in the final miscella, and the amount of solvent used per ton of cottonseed that is direct-solvent extracted. Less hold-up of solvent in the marc means more thorough extraction of oil in each stage, and appreciable overall reductions in solvent that must be reclaimed and recycled per ton of cottonseed processed. Figure 4 shows relationships between the same factors, but for a cottonseed prepress-solvent extraction operation; obviously, the gallons of solvent required to extract a ton of cottonseed are reduced as the result of prepressing the cottonseed to 12%–14% residual oil content. Similar contrasts occur between direct-solvent and prepress-solvent cottonseed extraction operations but, due to space restrictions, only the set of curves for direct-solvent extraction are presented.

Figure 5 shows relationships between percent hexane hold-up in the marc and the heat content of vapors from the desolventizer-toaster, at different vapor temperatures, per ton of cottonseed processed by direct-solvent extraction. The amount of energy input required to vaporize the undrained solvent increases both with solvent hold-up and vapor temperatures.

Direct steam injection generally is used to vaporize the held-up solvent, but moisture added to the meal must be removed later in a meal dryer. Relationships between solvent hold-up in the marc and energy required to dry the desolventized meal to a 10% moisture level are shown in Figure 6. Increased solvent hold-up in the marc also means increased energy costs in the meal dryer.

The higher the oil content in the exiting miscella, the less energy will be required to concentrate it to 65% oil content, the level typically used in miscella. These relationships are shown in Figure 7.

Relationships between total energy requirements (for solvent recovery, desolventizing in the DT and meal drying) per ton of cottonseed processed, DT vapor temperatures, and percentage hexane hold-up in the marc are shown in Figure 8 for a direct-solvent extraction operation. Similar relationships are shown in Figure 9 for a prepress-solvent extraction operation.

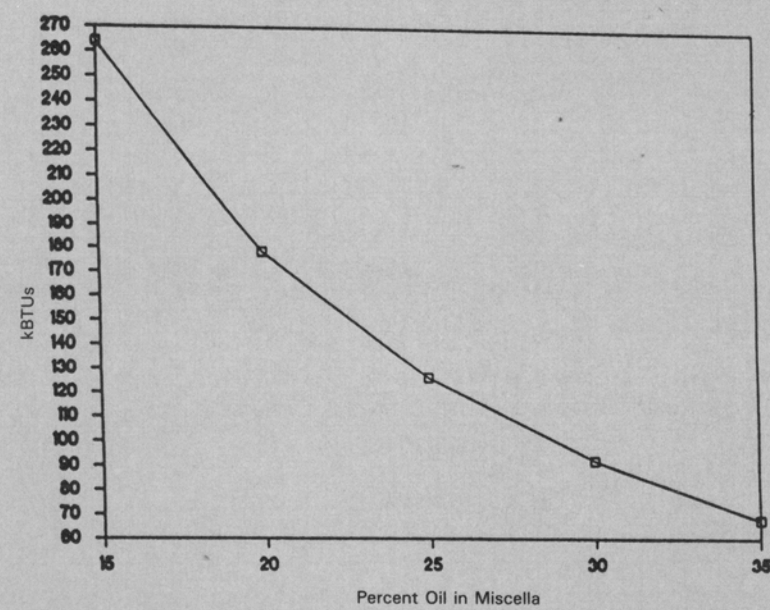

FIG. 7. Relationships between energy requirements to concentrate miscella to 65% oil content per ton of cottonseed processed, and oil content in extractor exit miscella, direct-solvent extraction process.

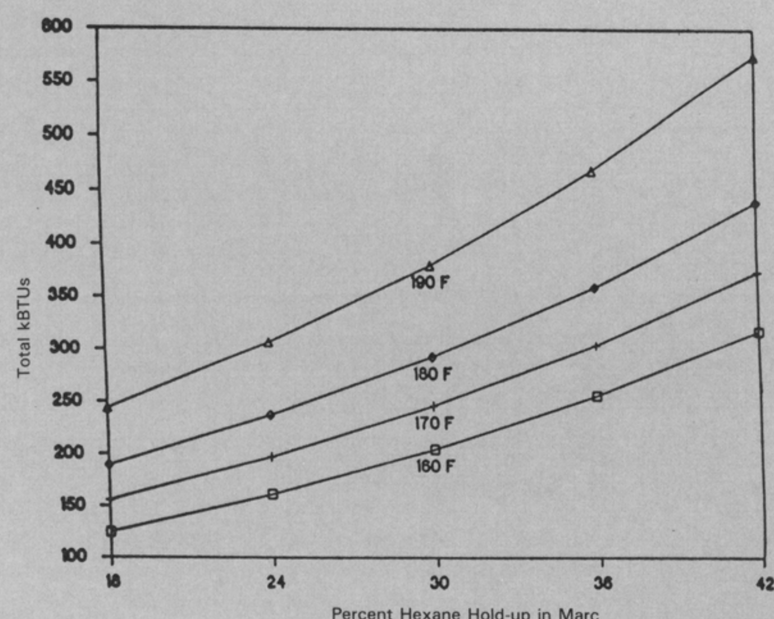

FIG. 8. Relationships between total energy requirements (sovent recovery, desolventizing, meal drying and miscella concentration) per ton of cottonseed processed, hexane hold-up in the marc and temperatures of desolventizer vapors, direct-solvent extraction process.

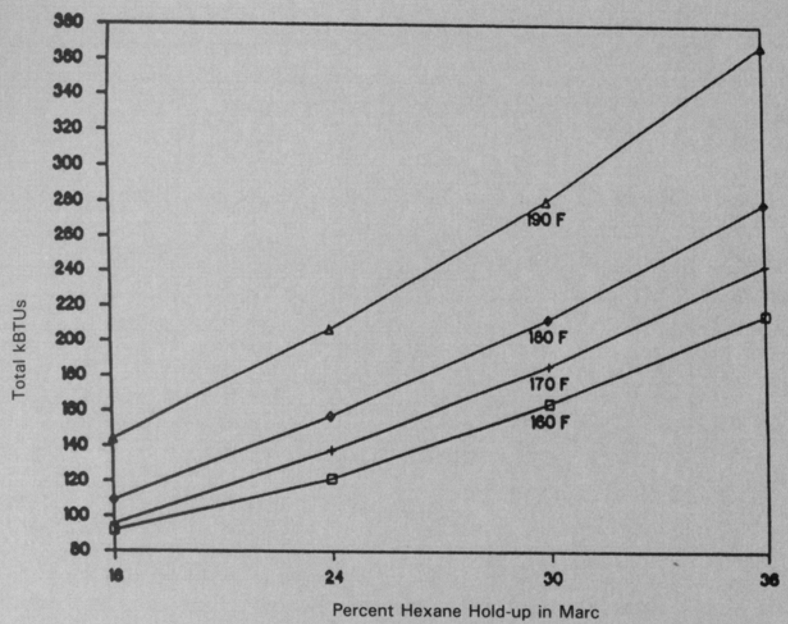

FIG. 9. Relationships between total energy requirements (solvent recovery, desolventizing, meal drying and miscella concentration) per ton of cottonseed processed, hexane hold-up in the marc, and temperatures of desolventizer vapors, prepress-solvent extraction process.

These data, plus reduced capital, maintenance and electricity costs, indicate a cost reduction of approximately $1/ton when an expander is introduced into a direct-solvent extraction cottonseed oil mill, and $1.50/ton when a screw press in a prepress-solvent extraction oil mill is replaced by an expander. Depending upon energy costs, the payback period for installation of an expander in a 500-TPD direct-solvent extraction cottonseed oil mill is estimated to be five to eight months, or up to a 200% return on investment in the first year if the mill has a long crushing season.

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Methods for Nutritional Assessment of Fats