Trends and Developments in Solvent-Extraction[1]

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WHEN recommending solvent-extraction over hydraulic and screw pressing, one no longer takes the defensive. The overwhelming success of solvent-extraction for soybeans is generally recognized. Also the economic values in solvent-extracting other fat- or oil-bearing materials, the products of which must compete with soybean oil and meal, are becoming more and more appreciated.

For many of the oil pressers the question has changed from "Why should we go to solvent-extraction?" to "How long before we have to convert to solvent-extraction? how much of our equipment can we keep when we convert? or which of the available solvent processes is best for our purposes?"

It is not proposed here to go into the economics for converting to or selecting solvent-extraction plants. Such discussions have been presented elsewhere (1). What is planned now is to describe new processes and the improvements in established processes. These are indicating trends and directions in which solvent-extraction technology appears to be moving. Knowledge of these developments should help in selecting a process or converting a pressing plant for the most suitable solvent-extraction in specific applications.

Extraction Processes

For treating soybeans there are several standard solvent-extraction processes from which to choose. Each has proven successful in several years of commercial operation. These processes have been described adequately in a number of publications (2, 3). Any of these established processes may be accepted with assurance for satisfactory soybean extraction. However personal preferences should be modified by local economic considerations and by an awareness of the recent improvements in standard soybean processes.

For handling cottonseed, second only to soybeans as the domestic source of vegetable oils, the solvent-extraction processes are not yet firmly established. However they are receiving a great amount of attention in development and research work. The higher oil content of cottonseed, its more variable quality, its gossypol content, and its fines-producing tendencies present special problems that have required major changes in existing processes and the evolving of new processes for acceptable solutions. Problems of similar nature exist with flaxseed, third ranking U. S. vegetable oil source, and with other high oil-content materials.

Prepressing followed by solvent extraction is being used effectively on cottonseed and the other high oil-content materials. The inducements are strong for continuing and extending this method as screw-press plants can convert readily at increased capacities to prepressing solvent-extraction plants. Most of their installed equipment can be retained, and only standard solvent extraction equipment, as used for soybeans, need be added. By cooking, then prepressing, a good part of the oil is removed from the seed, its undesirable quality variations are minimized, and the tendency to form excessive fines is reduced. Thus the resulting press cake compares with soybeans in ease of solvent extraction.

However there is a definite trend toward full solvent-extraction of the high oil-content seeds without prepressing. The standard extraction processes, modified for fines handling and with careful preparation of the oilseed, and the specially-developed, new processes appear to be successfully coping with the fines and other processing difficulties.

One of the new processes is the filtration-extraction system (4, 5). It is designed particularly for cottonseed, but claims are made for its versatility in processing other high-oil seeds as well as soybeans and rice bran. It was developed through the pilot plant stage by the Southern Regional Research Laboratory of the U. S. Department of Agriculture. The process has been licensed to several companies. Commercial plants have been designed and are offered under the names of Rotofil by the Blaw-Knox Company, Filtrex by Wurster and Sanger Inc., and Filtration-Extraction by the Lukenweld Division of Luken Steel Company. A 150-ton-per-day cottonseed plant that will handle soybeans also is now being put into operation by Lukenweld.

In this process, standard seed preparation equipment, such as is available in hydraulic-pressing plants, may be used. The delinted and dehulled cottonseed meats are rolled, cooked, and then "crisped" by evaporative cooling. Continuous countercurrent extraction is accomplished in two units, a horizontal, immersion type of mixing or soaking extractor and a horizontal, rotary, Oliver vacuum filter of fully enclosed, vapor-tight construction. The prepared meats are slowly conveyed through the miscella-filled, immersion extractor and discharged as a slurry onto the filter screen. From this point miscella of high oil concentration is drained from the meal by vacuum for oil recovery in the evaporators. Then as the filter screen rotates, it carries a bed of meal under solvent sprays of successively decreasing oil concentration with vacuum drainage between each wash. The miscella drained from the first wash is pumped into the immersion extractor for slurrying more meal. The last wash through which the meal bed is rotated is fresh solvent. This is drained off for the preceding wash. The fully extracted meal is removed from the filter screen by a revolving screw for conveying to the meal desolventizer.

A novel, continuous extraction process for cottonseed is offered by the Allis-Chalmers Company. It is called the Vibroil Process and involves a minimum preparation of the meats for extracting. The meats are ground in solvent while being extracted in a vibratory ball mill as they flow rapidly through it as a slurry. The meal is separated from the slurry and washed with pure solvent in an enclosed, continuous vacuum filter of drum-type construction. The drained miscella and wash liquor go to the evaporators, and the extracted meal is conveyed to the desolventizers for normal product-recovery operations. Screen size of the extracted meal is claimed to be comparable to that of extracted cottonseed meal now on the market.

A third process only recently introduced in the United States, though used for many years in other countries, is the DeSmet Process. The first U. S. plant has been in operation on the West Coast for over a year on copra, and another plant is now being put into operation in Minnesota for flaxseed and soybeans. The distinctive feature of the process is the extractor design. This involves a moving screen in the form of a continuous, horizontal belt upon which the prepared oilseed is fed in a thick, continuous layer. A series of nozzles, above the belt, are set to spray solvent of decreasing oil concentrations along the moving bed of seeds. Solvent percolating through the seed bed is collected in a series of conical pans and is recycled by pumping to the corresponding nozzles above the screen. Stage-wise, countercurrent extraction is obtained through overflow of the solvent from one pan to the next in the direction opposite to the movement of the seed bed. This overflow solvent increases in oil concentration as it moves from pan to pan until it is drawn off as strong miscella from the end pan. At the other end of the extractor the moving bed of extracted meal gets a final wash of fresh solvent, passes through a drainage area, and is discharged to the desolventizer.

Equipment Trends

The equipment in the newly-introduced processes just described and changes in the established soybean extraction equipment show definite trends that merit consideration. A major trend has been toward lower, horizontal designs of extractors. Until recently the only horizontal extractors in general use were the Kennedy Extractor and certain full immersion, screw-type extractors. It is interesting to note that in the three new processes described above horizontal extractors are used also. The popular, multi-story Bollman-type extractor has now been redesigned, for alternate acceptance, into "down-to-earth" models. Such newer designs as the horizontal basket-type extractors of the French Oil Mill Machinery Company and the Rotocel of the Blaw-Knox Company are examples of additional extractor design selections where lower building construction is preferred.

While losing the advantage of gravity flow of extracting liquid and requiring increased pumping facilities, these new, lower extractors have permitted better control and redistribution of the miscella in its successive flows through the meal. The stage-wise, countercurrent flow, such as has been described in the filter operation of the filtration-extraction system and in the extractor operation of the DeSmet Process, again appears in the new basket extractor designs and in the Rotocel extractor. The progressive, stepwise counterflow of solvent is ac-

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complished either by pumping it upstream to the meal flow or by recycling the solvent from each pan to the corresponding spray nozzle above it with overflow from pan to pan. In either case the solvent streams can be directed onto the meal at the preferred locations and in the amounts desired. The successive, solvent-flow quantities can be controlled from free percolations of droplets through the meal to complete floodings followed by successive drainages of the fully immersed meal.

This stage-wise flow should be recognized as a definite development in extraction operations. It should be given careful consideration when selecting an extraction process, particularly for high oil-content seed.

The other important equipment for solvent plants that has undergone marked transformations in design and operation is the desolventizer that evaporates the retained solvent from the extracted meal. The classical "schnecken" desolventizer, consisting of one or more vertical banks of horizontal, steam-jacketed screw-type conveyors, is still being effectively used in a number of plants. However there is a marked interest in and an increasing use of vertical, tray-type meal desolventizers. Some are modifications of the stack cookers used in seed preparation.

Through gravity fall and rotating scraper arms, the solvent-wet meal is moved across heated trays, in some cases past steam-jacketed sections of shell walls, and down through the desolventizer so that essentially all of the solvent is vaporized from the meal before discharge. Because of the controlled gradation of solvent removal, of moisture content, and of meal temperatures that are possible in the tray designs, this type of unit merits careful evaluation for new plant specifications.

The conventional desolventizing operation of applying jacketed, steam heat to the meal to vaporize the solvent and of using a small, final, direct steam sparge to free the meal of solvent vapors also has been subjected to modifications.

In the Blaw-Knox horizontal vapor desolventizer and in the vertical Allis-Chalmers tray-type desolventizer, part of the solvent vapor evaporated from the meal is superheated in a heat exchanger and recycled back through the meal. There it gives up its superheat for evaporating more solvent.

There is also interest shown in direct sparging of steam into the meal for purposes more than just the removal of the last traces of solvent. Direct steam is being considered for removal of appreciably larger amounts of solvent from the meal and for adjusting moisture content of the meal being desolventized.

One pound of saturated steam on condensing will evaporate about seven pounds of hexane solvent while adding a pound of water to the meal. This is an effective way of desolventizing if the increased moisture content can be tolerated and if "balling" up of the meal can be prevented. Evaporation temperature may be lower than the boiling point of the solvent because of stripping or steam-distillation action. Supplementary indirect steam heating through jacketed trays and walls is required to avoid excessive moisture condensation into the meal for this type of desolventizer.

The new combination Desolventizer-Toaster of the French Oil Mill Machinery Company effectively uses direct and indirect heating steam to produce a finished toasted soybean meal from a solvent-wet, extracted meal. A single vertical, tray-type and steam-jacketed vessel is used.

Other improvements in extraction operations are primarily minor modifications in meal handling and preparation and in feeding to and discharging from the extractor and desolventizer. For example, changes have been introduced in the basket design of the Bollman-type extractors to increase capacity, to facilitate handling, and to minimize channeling effects of the percolating liquid. Also, as an example, in the vertical, immersion-type extractor, V. D. Anderson Company has increased the volume of the upper section and baffled it to improve fines separation from the miscella, has designed a vertical feed screw for the upper center of the extractor for positive introduction of prepared seed, has made the slot openings in the trays adjustable to control extraction time, and has replaced the "plug"-type, meal discharge at the bottom of the extractor with a continuous conveyor called a "drainage runaround."

Such improvements that lead toward trouble-free plant operation can be appreciated by those familiar with the various problems that can arise on moving prepared seed and fines in contact with solvent.

Animal Fat Extraction Process

As for the solvent extraction of animal tissues, there have been no marked changes in the solvent batch processes following conventional rendering methods. Nor have there been modifications of any consequence in the standardized, horizontal batch extractor with its internal agitator and drain or filter pots. The depressed market prices for animal fats has discouraged maximum fat recovery by solvent methods. In fact, there is a growing movement to leave higher grease and tallow contents in animal feed meals. However intensified research is now going on to find new uses and derivatives for animal fats. This activity should eventually increase the demand and value of animal fats and justify improvements in batch extraction and the development of continuous extraction processes.

Much interest is now centered on the Chayen Process of shock-wave rendering used in British and Canadian plants (6). The fat cells are ruptured by sonic-frequency vibrations when animal tissues, immersed in water, are passed rapidly through a modified hammer-mill. This innovation also has diverted attention from solvent-extraction methods.

A new solvent process of azeotropic rendering and extraction of raw animal materials should have far-reaching effects on animal fat and meal production. In this process, raw, ground, animal material in contact with boiling solvent loses most of its tissue water by azeotropic evaporation with the solvent vapors while its fat is extracted by the hot liquid solvent. There are now two batch plants in commercial operation by the patented VioBin Process that directly separates raw animal tissues azeotropically into three components, water, fat, and meal. This combined solvent-rendering and extraction process also lends itself readily to continuous operation (7).

Extraction Solvents

Many different solvents have been studied and tried for use in fat and oil extractions. Few of these have reached the stage of actual production use in commercial plants. Since trichlorethylene has been practically eliminated for use in extraction of soybeans because of the toxic nature of the extracted meal, chlorinated hydrocarbons have been used only in a limited number of plants, mainly for the extraction of animal tissues.

Commercial petroleum fractions of hexane for oilseed and of heptane for animal materials are likely to remain in general use for years to come because of their availability, low cost, and over-all suitability as oil and fat solvents.

Evaluation of Progress

In view of the considerations presented here, it appears that the coming solvent extraction processes for oilseed will include careful preparation of the seed for full oil extraction with hexane in horizontal-type extractors. The counter-current, stage-wise method of extraction by spraying, draining, collecting, and repumping the solvent through each of a series of stations along the moving batches or layers of oilseed will predominate. The meal will be desolventized in most processes by vertical tray-type desolventizers with more effective use of direct steam and of solvent vapor for freeing the meal of solvent. No radical changes may be expected in the near future in the oil and solvent recovery operations.

Should there be a revived interest in the improvement of animal fat extraction methods, progress appears to be in the direction of continuous heptane-extraction operations and of combined, single-step rendering and extraction processes.

These are personal opinions based on observed trends and developments. However such envisioned designs could be replaced by radically new innovations whose simplicity, such as a quick, direct fat or oil recovery with minimum of material preparation, may revolutionize the whole industry. Such new departures from the general technology could possibly be suspected in the vibratory methods of vegetable oil and animal fat extraction.

REFERENCES

1. Becker, K. W., and McCubbin, K., J. Am. Oil Chemists' Soc., *30*, 554-57 (1953).
2. Cofield, E. P., Chem. Eng., *58*, No. 1, 127 (1951).
3. Encyclopedia of Chemical Technology, Vol. 6, "Liquid-Solid Extraction," 97-100 (1951).
4. D'Aquin, E. L., *et al.*, Ind. Eng. Chem., *45*, 247-254 (1953).
5. Gastrock, E. A., D'Aquin, E. L., and Vix, H. L. E., Cotton Gin and Oil Mill Press, *53*, 31-7 (May, 1952).
6. Chem. Eng. News, *30*, No. 50, 5266 (Dec. 15, 1952).
7. Levin, E., and Lerman, F., J. Am. Oil Chemists' Soc., *28*, 441-444 (1951).

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