Batch and Continuous Solvent Extraction

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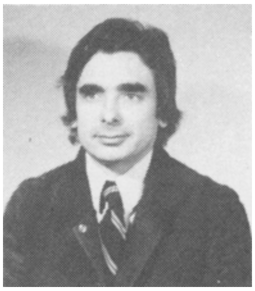

ABSTRACT

Two physical processes are used for the removal of oil from oilseeds, one called "solution extraction" and the other "diffusion extraction." In batch type solvent extraction plants, a diffusion process takes place. Due to their high steam and labor requirements, such plants are being steadily replaced with continuous solvent extraction plants, whose main component is the extractor which can be either of the immersion or percolation type. The combined use of these two types of extractor makes it possible to extract oil directly from oilseeds, even if they have a high oil content, with no need for continuous screw presses or expellers. Comparative data on the processes in most common use are given.

REMOVAL OF OIL FROM OILSEEDS IN BATCH AND CONTINUOUS SOLVENT EXTRACTION PLANTS

The removal of oil from oil-bearing materials calls for a careful study of their nature and main characteristics, among which the following deserve particular mention: oil or fat content, particle size, and preparation of the material. It is upon these factors that selection of the most suitable type of equipment should be based.

Extraction of oil from oil-bearing materials of plant or animal origin is usually done by pressing by means of continuous screw presses or by extraction with volatile solvents. Solvent extraction plants can be of the batch or continuous type. In their turn, continuous plants can be percolation plants, immersion plants, or direct extraction plants.

Oilseeds to be processed may be divided into two groups: those with a low oil content (18-20%) and those with a high oil content (above 20%). As a general rule, oilseeds with a low oil content, such as soybean, grape seed, rice bran, and dry milled corn germ, are subjected to both continuous and batch solvent extraction. High oil seeds, such as rapeseed, peanut, cottonseed, sunflower seed, and copra are extracted in two stages, pre-pressing and solvent extraction, or, as has recently been the case, in a single step by the continuous direct solvent extraction system.

During the contact time between seed and solvent, two extraction processes occur simultaneously, one faster than the other. In fact, it can be verified that the larger portion of readily available oil derives from the oil-bearing cells broken in the preliminary processes of grinding, cooking, pressing, or flaking, whereas the smaller portion that is most difficult to extract is in the intact or only partially ruptured cells. Removal of oil from the latter cells requires a longer time and takes place by osmosis. The oil contained in the cells tends, in fact, to pass through the cell walls into the oil-solvent solution of lower concentration. As a result, two processes may be distinguished which will be called "solution extraction" when the oil is obtained from ruptured cells and "diffusion extraction" when the oil is derived from cells that remained intact.

Experimental research has further confirmed that the extraction time, as a function of the quantity of oil extracted, may be represented by an almost linear function down to a residual oil content of 5%, whereas below this figure the function has a curvilinear shape, as shown in Figure 1.

Seeds of a low oil content (soybean) are easily extracted upon treatment with solvents after preliminary treatment by reduction and cooking causing extensive cell breakage. Unfortunately, this cannot be applied to high oilseeds since in this case extensive cell destruction involves serious technological problems because of the high oil content of the material which tends to agglomerate during the cooking-preparation stage. It is, therefore, necessary to carry out a partial reduction of the seed, remove the oil that has come out of the cells either by mechanical expression or by means of a preliminary solvent extraction process to reduce the oil content of the material to 10-15%, then break the oil cells that remained intact, and subject the partially defatted material to a final solvent extraction process. In this way no problems are encountered during reduction of the material inasmuch as its low oil content allows complete breakage of the cells and subsequent easy removal of the oil.

BATCH SOLVENT EXTRACTION PLANTS

Batch extractors are principally used for the recovery of oil from cakes obtained after expelling or from low oil and ligneous materials such as grape seed and olive pomace. The material to be extracted should have a minimum content of fines. The major obstacle to these extractors is discharge of the extracted residue since some kinds of oilseed tend to agglomerate during recovery of the solvent, which is generally done by means of live steam blown through the mass of spent material. To overcome this problem, some extractors have been equipped with internal stirrers, but the high power requirements and consequent mechanical problems have rendered this system uneconomical.

A standard batch solvent extraction plant consists of four or more stationary extractors of cylindrical design with dished bottoms, provided with a charging door at the top and an unloading door at the bottom (Fig. 2).

The material to be extracted is charged into the extractor by gravity until it is completely filled. The extractor is equipped with an internal perforated metal plate covered

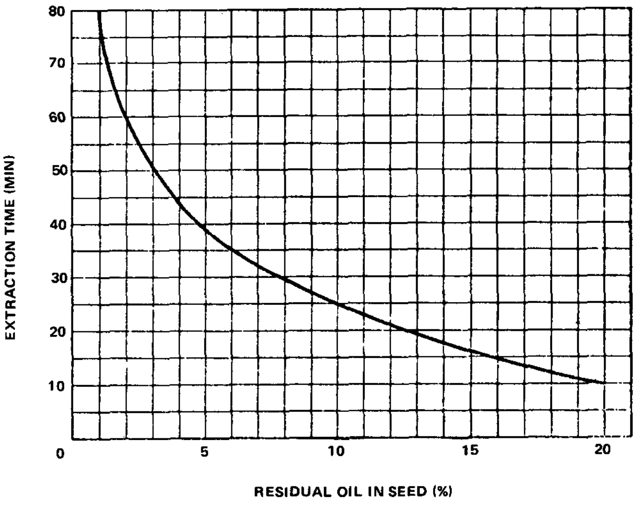

FIG. 1. Relation of extraction time to residual oil left in the meal.

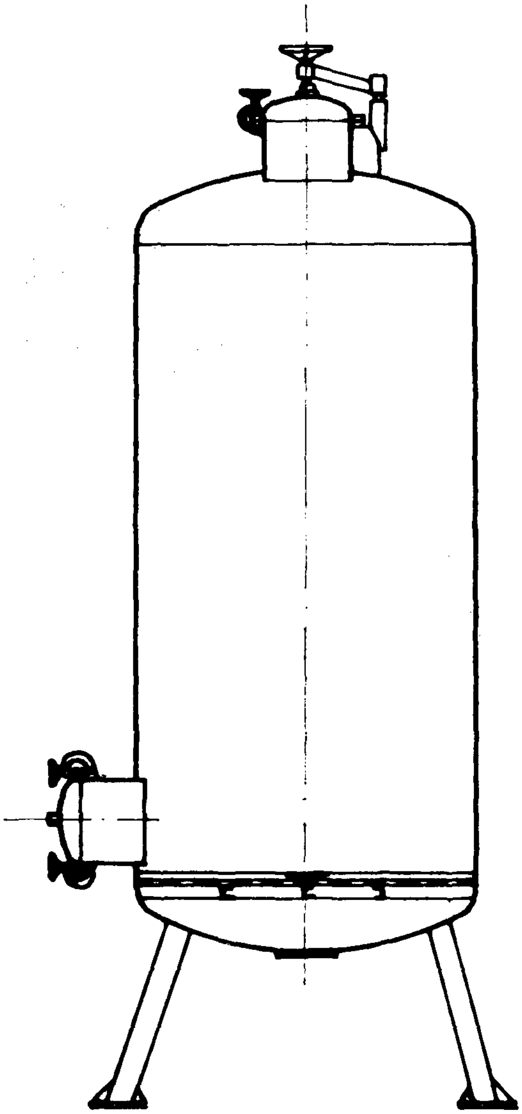

FIG. 2. Batch extraction unit.

with a filter cloth. Upon completion of loading, the extractor is filled with solvent and set in cycle with the other extractors which are already extracting material. The miscella enters in succession the extractors containing material of progressively increasing oil content, and the spent material is finally extracted with fresh solvent before being discharged. Upon completion of washing, which generally varies from 8 to 10 hr, live steam is admitted to the extractor to distill the solvent retained by the spent material. After desolventizing, a pressure of 0.5-1.0 kg/cm^2 is built up in the extractor, the unloading door is immediately opened, and the extractor contents are automatically discharged by the effect of pressure. After discharging the material, the door is closed, and a new batch of material is charged into the extractor, which is again set into the operating cycle.

The complete plant is equipped with four extraction tanks as shown in Figure 2 plus the ancillary equipment including miscella filters, continuous distillation facilities to remove solvent from the miscella, and a system to recover the solvent.

Utility and material requirements per ton of material processed in this type of plant are usually the following: steam, 600-700 kg; power, 6 KWH; water, 15 m^3; and solvent, 5 kg.

In recent years, however, due to their high requirements and the impossibility of handling large amounts of materials, batch extractors are being replaced with con-

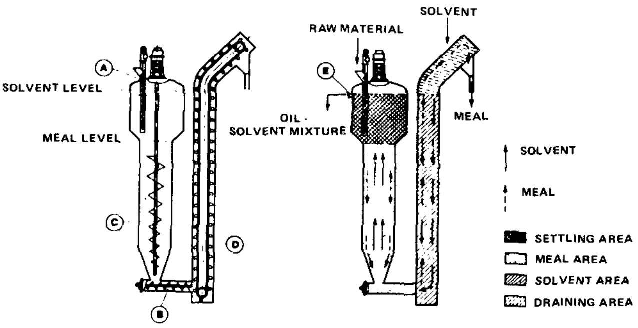

FIG. 3. Cross section of the immersion extractor.

tinuous systems, which achieve the highest economy of steam, labor, and materials.

CONTINUOUS SOLVENT EXTRACTION PLANTS

Immersion Extractors

A continuous system where the diffusion process occurs most intensively is the immersion extractor (Fig. 3).

The material to be extracted enters the immersion extractor through the dosing unit (A). The extractor housing is divided into two areas. The top acts as a settling area for the miscella and the lower part as an extraction area. In the latter area the material is gently agitated by the screw stirrer (C) which provides an intimate and homogeneous contact between material and solvent. The action of the screw stirrer also prevents packing of the material as this tends to ascend to the top of the cylindrical housing and then to fall by gravity along the housing walls. The extracted material coming out of the extractor bottom is removed by the metering screw conveyor (B) and conveyed to the elevator (D). The level of material in the extractor is maintained constant. The meal is taken by the elevator (D) and lifted up in a path countercurrent to the fresh solvent, which is admitted at the top of the elevator. While progressing in its ascending path, the meal leaves the solvent bath, is drained off as it is held in a series of baskets with perforated bottoms, and is finally dumped into the desolventizer. The solvent flows in a counter direction, as indicated by the arrows, and thus countercurrent extraction takes place.

This type of extractor is specially designed to handle materials which are difficult to prepare and to extract and principally materials which are in a comminuted form. These materials cannot be handled in standard percolation extractors because of poor drainage through the fines unless provision is made for special pelletizing equipment. Even this often does not work and is very expensive.

More than 60 units of this type have been built by our company, and they are handling a great variety of materials, such as rice bran, cocoa skin, cracked bones, acorn meal, corn germ, fish meal, and expeller cakes.

Percolation Extractors

In this system the previously described "solution extraction" process takes place in an ideal manner. An extractor of this type made by our company is schematically shown in Figure 4.

The material to be extracted enters a special charging hopper [1], and its constant level is ensured by an adjustable volumetric device. The material is dumped into the basket near the top of the descending side of the chain. As the baskets are filled with material and start down the descending side, solvent is sprayed onto them and an extraction process by percolation of solvent through the flake mass begins. This is a multiple extraction process carried out under programmed countercurrent conditions so that the miscella of low oil concentration is brought into contact with material with the least oil in it and vice versa.

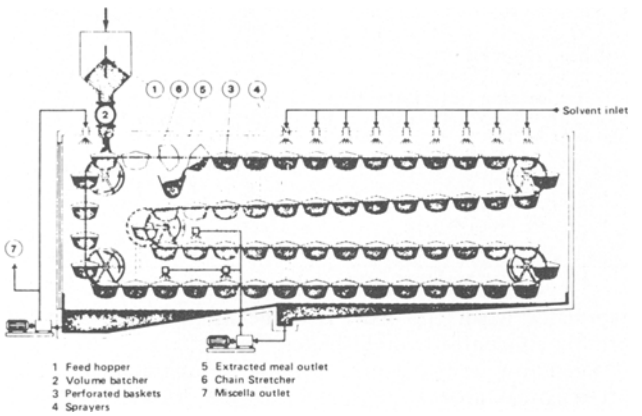

FIG. 4. Sectional view of the percolation extractor.

Under these conditions, ca. 40 washings are given by only two pumps. The special shape of the baskets and the volumetric dosing system ensure a uniform and shallow bed of material, which is never higher than 50 cm. Under these conditions, there is no possibility of channeling solvent or miscella flow through the flakes and consequent incomplete extraction of some areas. In the extractor the solvent or miscella percolates by gravity through four superimposed beds of material each 50 cm thick. Thus a 2 m thick bed of material is extracted without risk of uneven compacting of the material and consequent channeling and incomplete extraction.

DIRECT SOLVENT EXTRACTION OF HIGH OILSEEDS BY THE COMBINED USE OF THE PERCOLATION AND IMMERSION EXTRACTORS

This process was first developed and applied on an industrial scale by our company and has been patented under the name "Direx." By this system it is possible to remove completely the oil contained in the oilseeds, even if they have a high oil content, with no need for pre-pressing.

The sequence of the processing steps is the following:

1. Preparation of the seed, which is generally very simple inasmuch as it consists of cleaning-decortication, where required, cooking and reduction of the material.
2. Partial extraction of the oil in the percolation extractor until lowering the oil content of the seed to values ranging from 10 to 15%, even if the incoming oil content is as high as 60%.
3. Wet flaking of the partially defatted seed as it comes out of the percolation extractor. This operation is carried out in a special solvent-tight flaker operating in a solvent vapor-saturated atmosphere.
4. Final extraction of the flaked material in a second extractor of the immersion type, as described previously.

Extraction Unit

The operation of the "Direx" unit is described in Figure 5.

The fresh solvent enters at point C, descends through the elevator, and ascends to the top of the immersion extractor [3] containing the partially defatted material. By overflow the miscella passes into the first spouts of the percolation extractor [1] where it is brought in succession in contact with seed of increasingly higher oil content. In this way a highly concentrated miscella is obtained. The final miscella is then pumped to the subsequent filtration, preconcentration, and distillation stages. The seed coming from the preparation room enters the percolation extractor through the metering unit (A), is partially extracted down to a residual oil content of 10-15% (for some kinds of seed even 3-4%), is then conveyed into the flaker [2] and finally into the immersion extractor [3] where it is completely extracted. The totally defatted meal is dumped into the desolventizer-toaster [4] for solvent removal.

The fundamental step for an efficient performance of the "Direx" process is carried out in a flaker operating in a solvent-tight housing saturated with solvent vapors, which affords maximum reliability of service, as confirmed by the safe operation of such plants. This is further proved by the fact that the centrifugal pumps normally used in solvent extraction plants do not present any danger, even though they revolve at a speed of 1,400 rpm, as they operate in a solvent saturated atmosphere. The flaker runs at a low speed, and the rolls always revolve at the same number of revolutions, thus operating only by flattening and never by grinding. The flattening pressure is extremely low as the material to be flaked is very soft, being impregnated with solvent. Cell breakage is therefore very easy and complete, thus facilitating the subsequent solvent extraction step.

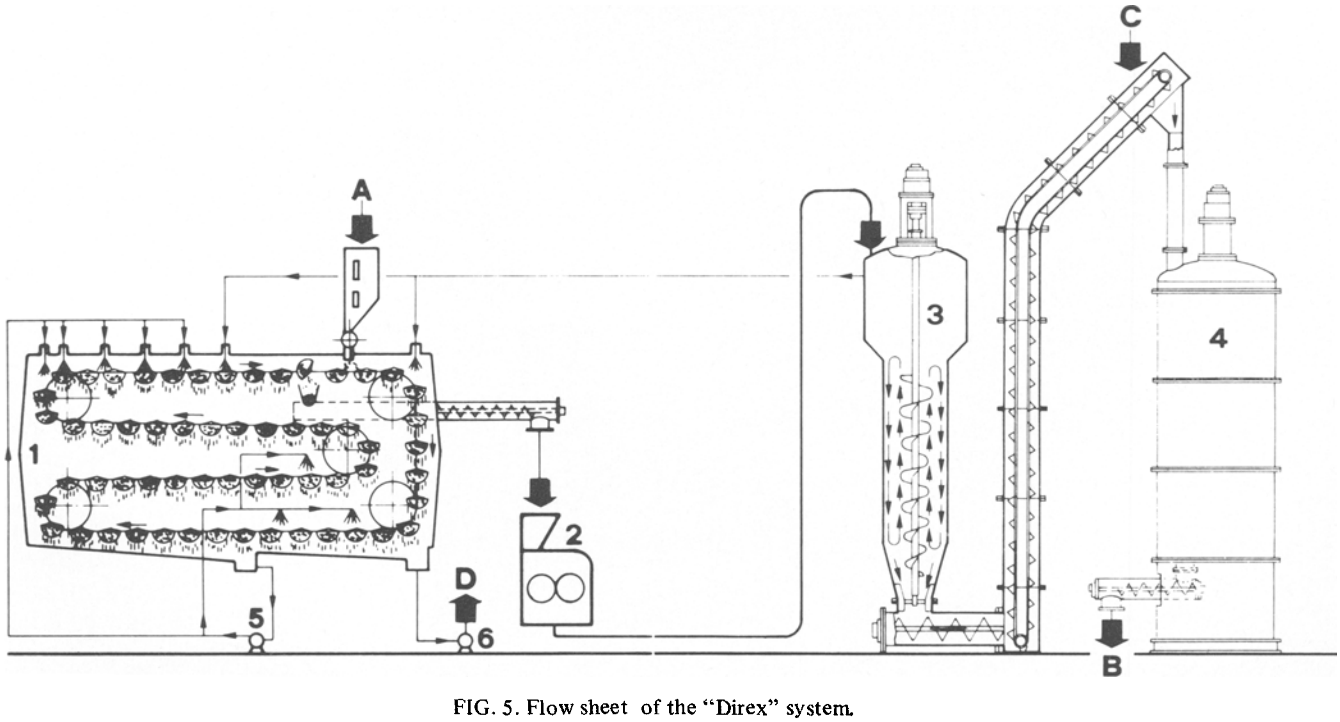

FIG. 5. Flow sheet of the "Direx" system.

TABLE I

Comparison of Solvent Extraction Systems

Requirements per ton		Pre-pressing and batch solvent extraction system	Pre-pressing and continuous solvent extraction system	"Direx" system
Steam	kg	700	280	290
Power	KWH	45	55	29
Water	m^3	14	12	15
Solvent	kg	5	4	4
Labor	hr	0.8	0.5	0.2

Some of the main advantages of the direct extraction system are lower capital investment, reduced maintenance costs, lower utility and material requirements, minimum labor requirements, and better quality of the finished products.

Quality of the Finished Products

In the "Direx" plant the seed is extracted at a low temperature (maximum 50 C), and the operating temperature never exceeds 105 C in the subsequent meal desolventizing stage. The latter factor is extremely important, especially when the meal is to be further processed into protein concentrates and isolates.

Such low temperatures cannot be maintained in the pre-pressing process inasmuch as the material is to be subjected to increasingly higher pressures in the expeller cage and the operating temperature ranges from 150 to 180 C, which causes some deterioration of the meal.

Table I lists the utility and material requirements per ton of seed processed which are recorded in the direct extraction system, conventional pre-pressing and batch solvent extraction procedure, and pre-pressing and continuous solvent extraction system.