Technical News Feature

Conditioning of Oil-Bearing Materials for Solvent Extraction by Extrusion

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ABSTRACT

A new procedure, based on extrusion, was developed to prepare soybeans for direct solvent extraction. The procedure eliminates the need of controlled cracking, partial shell remotion, heating and flaking, requiring only an adequate communition to particles passing Sieve USS 14 followed by extrusion in a specially developed extruder. Extruded soybeans were obtained in the form of hard and porous agglomerates, without any dusting tendency, higher extraction, draining and percolation rates, lower solvent hold up and higher apparent density than the best possible flakes. Extruded soybeans were processed by solvent extraction in batch and continuous industrial installations, enabling substantial increases in capacity (up to 100%) and reduction in overall steam consumption (up to 30%) when compared with flakes processing. Extracted oil from extruded soybeans seems to show lower levels of gums and toasted meal at higher soluble protein levels for the same urease activity. Peanut press-cakes were preconditioned by extrusion before solvent extraction in batch-type installations, enabling a substantial reduction in residual oil for similar conditions with nonextruded press-cake. For existing plants, the new procedure allows a substantial increase in plant capacity and lower steam consumption. For new plants, the new procedure allows substantial capital savings in equipment and space. The new procedure enables soybean processing by direct solvent extraction in small batch-type installation, which may be very convenient for some underdeveloped areas.

INTRODUCTION

The traditional and accepted method of soybean preparation before solvent extraction requires many steps: receiving and cleaning, drying, bean cracking, dehulling, bean heating and flaking. The scope of all preparatory steps is to obtain a flake of balanced and adequate characteristics, for high extraction rates, high draining rates, easy desolventizing after extraction and high percolation rates.

In order to achieve these results, bean cracking, bean heating and bean flaking are critical. Coarsely cracked beans will increase power consumption in the flaking process and produce large, breakable flakes, whereas finely cracked beans will decrease power consumption in flaking and produce smaller, dusty flakes. Higher temperatures in bean heating will increase pliability and reduce power requirements at the cost of more steam consumption. Excessive heating or inadequate mixing during heating can damage quality of the oil and meal. The capacity of the flakers will depend on the size of cracked particles, temperature and moisture of bean particles and desired flake thickness. Thinner flakes will increase the rate of extraction, but will also reduce percolation rates because of higher pliability and the dusty nature of these flakes, which tend to seal off the passages in the bed. Thicker flakes will reduce the rate of extraction and result in higher residual oil.

Reconciling so many variables to have consistent performance in oil extraction is not easy, although this can be done with skilled operators, very close supervision and care in maintenance of the equipment, among other factors. However, the cost is high.

The preparation procedure described in this paper was developed in a small oil plant (30 ton/day) owned by the author; it was probably the only extraction plant in the world that directly extracted oil from soybean flakes in batch extractors. The problems caused by the variation in flaking conditions were numerous. The new procedure is based on an adequate extrusion process, in which the explosive vaporization of water, present or added, ruptures all oil cells in the bean, leaving the oil free in a very permeable matrix of adequate mechanical resistance. The preparation for soybeans processing will consist of receiving and cleaning, adjusting moisture to 10-12% if necessary, bean grinding and extrusion. Extrusion can be performed very easily under controlled conditions, with simple equipment needing little maintenance. The advantages of the extrusion process are: (a) lower steam and power consumption; (b) reduction in process and transportation equipment; (c) less space required; (d) elimination of dust problems; (e) higher extraction rates than the best flakes; (f) higher percolation and draining rates; (g) easier desolventization because of lower solvent hold up; (h) higher capacity of available extractors because of higher extraction and percolation rates; (i) better chances to have improved quality in oil and meal because of lower processing temperatures and heating times.

After the extrusion procedure was adopted, the small plant increased its capacity ca. 3 times and became a very efficient, profitable unit. Extrusion conditioning was later used very successfully in oil extraction plants all over Brazil, mainly for continuous processing and large-scale plants (2000-3000 ton/day) with some deviations in the basic concepts to permit utilization of available equipment.

EXPERIMENTAL PROCEDURES

Soybean Preparation

Soybeans with a moisture content of 10-12% were comminuted to particles that passed through Sieve USS 14, in a hammer mill (3/16 in. openings in sieve) and roll mill (wheat milling type). Comminuted soybeans were fed to an extruder (Fig. 1) composed of 3 parts: (a) a worm feeder for constant adjustable feed rate; (b) a conditioning chamber (schnecken type), where the material could be heated and moistened with 1-2% open steam and/or water, if necessary to bring it to a 12% moisture content; (c) an extrusion chamber with appropriate exit nozzles where the conditioned material was first compressed and then expelled through the nozzles. Extruded agglomerates left the nozzle at a temperature of 85-115 C and were transported to the solvent extraction plant by conveyor, where they were cooled to ca. 60 C before reaching the extraction plant. Tests were performed using 2 models of extruders: 6 in. with 40 HP motor, processing an average of 1450 kg/hr soybeans; 8 in. with 75 HP motor, processing an average of 3100 kg/hr soybeans.

Batch Extraction of Soybeans

Batch extraction was performed by countercurrent in a

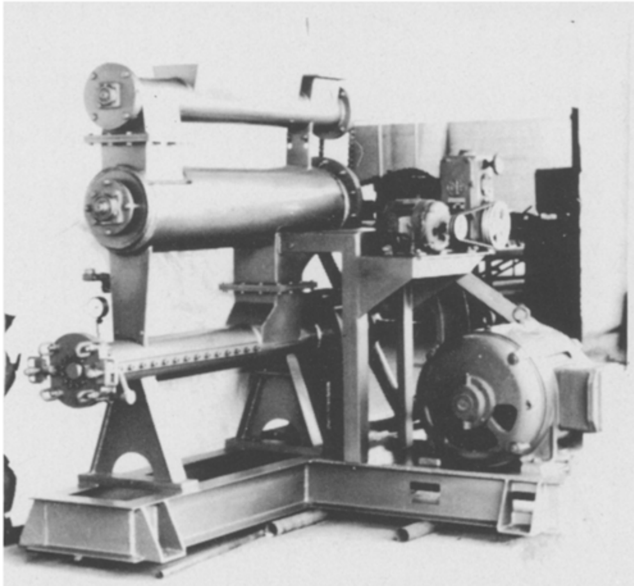

FIG. 1. Extruder for soybeans conditioning with feeder and mixing chambers.

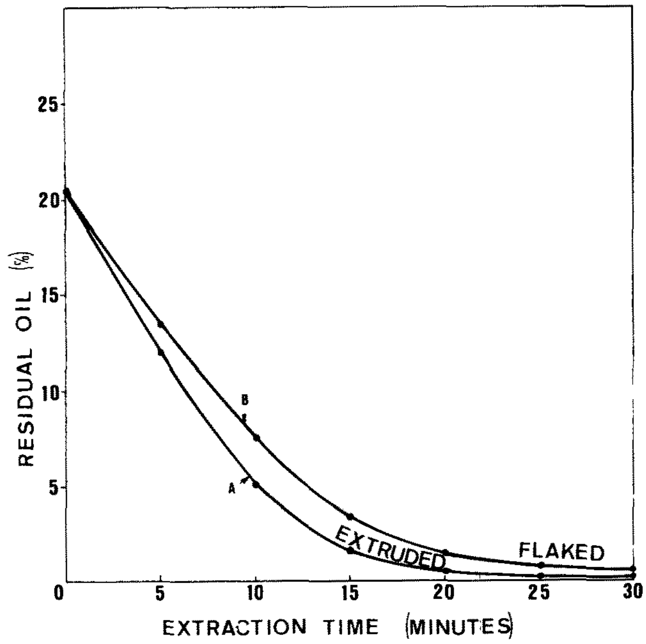

FIG. 2. Extraction rate of soybean oil.

battery of extractors, with the following basic characteristics: capacity of extractor, ca. 5500 lb. of agglomerates; extractor available, 5; daily capacity of plant, 95 ton/24 hr; typical operating conditions, solvent = solid ratio 0.9; average micela concentration = 21%; counter current operation with simultaneous washing of 4 extractors.

Continuous Extraction of Soybeans

Continuous extraction was performed in a rotary extractor, similar to a Rotocel, with 6 extraction stages. The specifications were: diameter, ca. 10 ft; bed depth, ca. 5 ft; daily capacity, 150 tons; typical operating conditions, solvent solid ratio = 0.72; average micela concentration = 26%.

Batch Extraction of Peanut Press-Cake

In one batch extraction plant, peanut press-cake from expellers was conditioned by extrusion and the expanded material was extracted with the normal expeller press-cake (in separate jute bags) to evaluate the influence of extrusion. Extraction characteristics of flakes and extruded agglomerates were determined in laboratory according to the following procedures.

Extraction rates. Oil extraction rates of flakes and agglomerates were determined according to the procedure described by M. R. Wingard and W. C. Shand (1). Results are given in Figure 2.

Percolation rate. Percolation rates were compared in the assembly shown in Figure 3 composed of: (a) a 5 gallon solvent can with level gage and valve; (b) a 1 L oil can (diameter, 0.28 ft; height 180 mm), with bottom replaced by a H-14 USS screen; (c) a 5 gallon collecting can with level gage. The following procedure was used. First, a 6 in. bed of material was placed in the 1 L can, then commercial hexane was placed in the 5 gallon solvent can. The flow of solvent from solvent can to collecting can, through the bed of material, was adjusted at the valve so a steady liquid layer was held on the surface of bed. At the flow conditions described the volume of liquid percolated through the bed (V) in a certain time (T) was recorded, superficial liquid velocity was calculated as 16.24 V/T ft/min and the percolation rate was calculated as 60 × superficial liquid velocity and expressed in cubic ft/sq ft × hr.

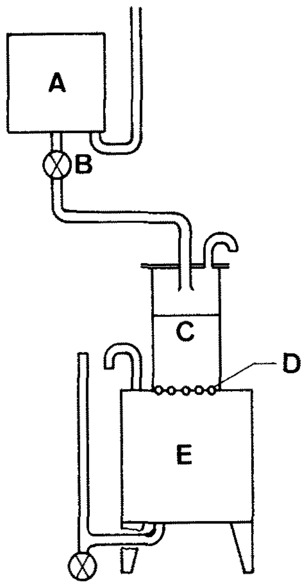

FIG. 3. Assembly for comparing percolation and draining rates: A—solvent can; B—valve; C—soybean holding vessel; D—screen; E—micela collecting can.

Draining rates. In the same assembly (Fig. 3), the flow of solvent was stopped, and the volume of liquid drained to the collecting can was measured at definite time intervals in the level gauge.

Solvent hold up. When draining of solvent ended, the content of the bed can was weighed and the solvent present was eliminated by evaporation. The loss of weight in evaporation divided by the weight of residual solids multiplied by 100 was considered the liquid hold up expressed in parts of solvent per 100 parts of solids. The calculation of liquid hold up and superficial liquid velocity from flooding to drained conditions was from the data obtained during draining and the final solvent hold up. This data is shown in Figures 4 and 5. Solvent hold up in plant operation and liquid retention of solids in plant operation were determined in samples collected before desolventizing. All analyses were performed according to the AOCS official methods.

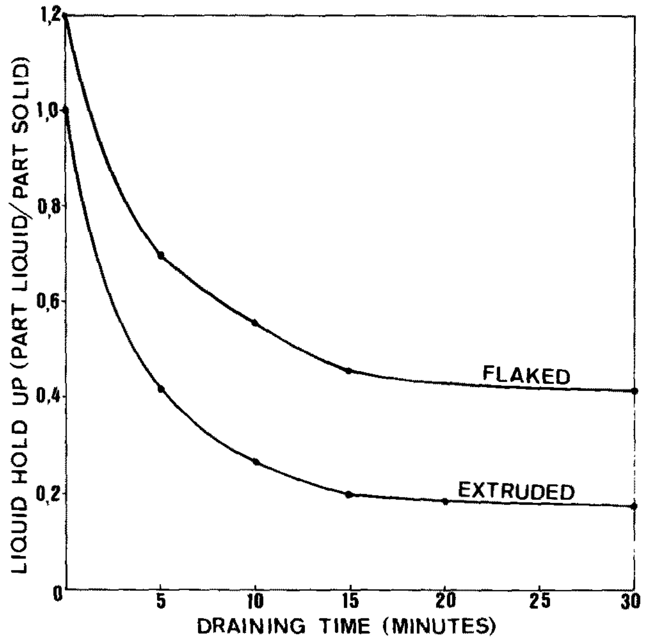

FIG. 4. Liquid hold up of soybeans in solvent extraction.

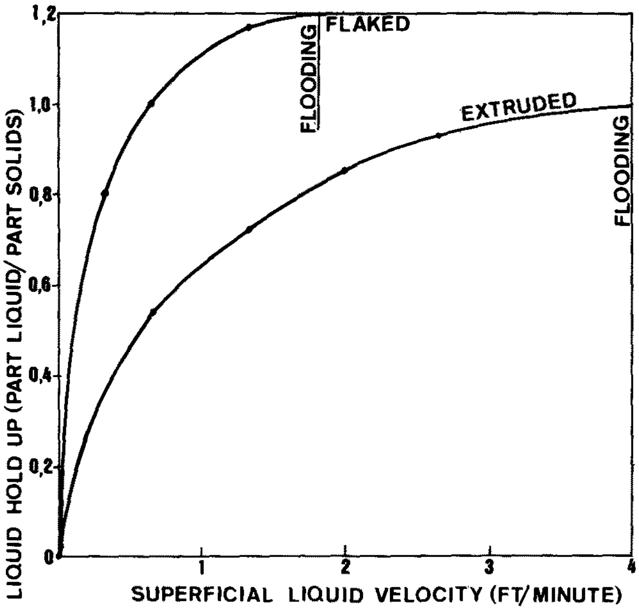

FIG. 5. Flooding rates of soybeans in solvent extraction.

RESULTS AND DISCUSSION

Characteristics of extruded agglomerates and flakes are shown in Table I. Extraction rates are shown in Figure 2. Results of liquid hold up in laboratory tests are: extruded soybeans, 17.2 parts liquid/100 parts solids; flaked soybeans, 42.5 parts liquid/100 parts solids. Results of percolation rate in laboratory tests are: extruded soybeans, 240 cubic ft/sq ft × hr; flaked soybeans, 76 cubic ft/sq ft × hr. For plant results with soybeans, see Table II. For plant results with peanut press-cake, see Table III.

DISCUSSION

Laboratory and plant data show that conditioning by extrusion seems to be a very satisfactory procedure for preparing for solvent extraction. The milling step before extrusion is not very critical, according to the experience acquired in more than 3 years of operation; substantial variation in this milling step is possible, depending on available equipment and local cost of utilities, provided particles in the range of 1-2 mm size are obtained. Cracking with a hammer mill, followed by final milling in corrugated roll mills, enables a very simple arrangement that will have energy consumption in the line of 5 Kwh/ton soybeans.

The basic points of conditioning by extrusion follow. The present or added water is completely diffused into the mass because of the pressure (up to 100 kg/cm^2) developed inside the extruder. When this pressure is released at the nozzles, the sudden vaporization of this water completely ruptures almost all oil spherozomes, releasing the oil into the extruded mass. The gelatinization of starches and hydration of proteins creates a binding agent uniformly distributed in the mass. The vaporization of the water promotes expansion of the material at the nozzle exit, whereas the binding agent tends to agglomerate the particle; the result is a permeable agglomerate of very good mechanical strength, no dusting tendency and high specific gravity, presenting very favorable conditions for solvent extraction. The material stays in the extruder for 15-25 sec, depending on process conditions and, as the temperature is low, protein denaturation or damage to the oil is unlikely. A substantial portion of the phospholipids are hydrated and are not extracted with the oil, resulting in oils of lighter colors and less gums.

With the relatively small extruders used, power consumed in extruding was ca. 15 Kwh/ton soybeans. Thus, the total power consumption in conditioning is ca. 20 Kwh/ton soybeans, which seems to be satisfactory when compared with the usual values for the flaking procedure

TABLE I

Characteristics of Extruded Agglomerates and Flakes

	Soybean (whole)	Soybean after hammer mill	Soybeans fed to extruder	Extruded soybeans[a]	Soybean flakes
Moisture	11.3%	–	11.24%	10.92%	11.2%
On USS 10	–	10%	–	–	–
On USS 20	–	35-58%	–	–	–
On USS 60	–	45-28%	–	–	–
Through USS 60	–	5-4%	–	–	–
Through USS 14	–	100%	–	–	–
Apparent density	–	–	–	600 kg/m^3	320 kg/m^3
Total oil content	–	–	–	20.54%	20.54%
Thickness	–	–	–	–	0.014"

[a]Cylinders ½ in. × 1.12 in. in length were used.

TABLE II

Plant Results—Soybeans

	Extruded		Flaked	
	Batch extraction	Continuous extraction	Batch extraction	Continuous extraction
Final micela concentration	21	28	21	25
Residual oil in meal (12% moisture)	0.45	0.34	0.54	0.56
Liquid hold up (% liquid/100 parts solid)	20	18	45	38

TABLE III

Plant Results—Peanut Press-Cake[a]

	Residual oil in extracted press-cake	
	Nonextruded (%)	Extruded (%)
	2.02	0.96
	1.93	1.15
	2.12	0.83
Average	2.05	0.98

[a]*Oil content, 10%; moisture, 6%.*

(15 Kwh/ton + 60 kg steam/ton). The capacity of extruders can be substantially changed by changes in operating speeds, nozzle geometry and moisture content; these changes will modify the characteristics of the extruded soybeans. Additional work is required to optimize the procedure.

When soybeans are extruded at a moisture level of 18%, the power required drops to ca. 5 Kwh/ton but an additional drying step is required in order to reduce moisture to a 10-12% level before solvent extraction; many plants operate this way in Brazil, but, at this stage, the oil is free in the matrix and any air drying will favor oxidation. With specially designed extruders of larger capacity, e.g., 10 ton/hr of 12% moisture soybeans, power needs will be no higher than in the usual flaking procedure.

Extraction curves (residual oil × extraction time) for flakes and agglomerates seem to indicate that releasing oil from pherozomes and fibrous capillaries is much more effective when extrusion is used than flaking. In other words, rupturing spherozomes by extrusion is more effective than flaking. Considering that the oil released is extracted by simple dissolution in the solvent, while the unreleased oil has to diffuse through walls, the straight part of the curves can be interpreted as extraction by simple leaching. Taking points A and B at the end of the straight part as typical, we could say that $(20.54 - 5.11) \times 100/21.54 = 75.12\%$ of oil was released by extrusion, whereas only $(20.54 - 8.5) \times 100/20.54 = 58.6\%$ of oil was released by flaking. These curves seem to provide a very good way to control the efficiency of the conditioning operation for oil extraction.

If desired, the expansion at the nozzle exit can be done in a vacuum chamber, resulting in adiabatic evaporation of water with production of very hard, permeable agglomerates with low moisture content (3-5% depending on temperature and vacuum); this result may be very attractive when solvents such as ethanol are used in oil extraction. Because of lower solvent hold up, the steam consumption in desolventizing extruded soybeans is substantially lower than in desolventizing flakes. In some experiments, the amount of soluble proteins in meal was higher at the same urease activity level, when the soybeans were conditioned by extrusion instead of flaking (26-30% soluble proteins against the usual 20% soluble protein). These results, however, are not conclusive because many possible interferences may occur in plant operation. From the data obtained, based on long used operating methods in many Brazilian plants, the extrusion conditioning of soybeans and some other seeds or press-cakes deserves attention as a very promising procedure in vegetable oil processing.

REFERENCE

1. Wingard, M.R., and W.C. Shand, JAOCS 26:422 (1949).

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