Dry Extrusion as an Aid to Mechanical Expelling of Oil From Soybeans

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A new concept is described for mechanical extraction of oil from soybeans, using dry extrusion as a pretreatment. It was found that coarsely ground whole soybeans at 10 to 14% moisture could be extrusion cooked so that the extrudate emerges from the die in a semi-fluid state. The dwell time within the extruder was less than 30 seconds, and the temperature was raised to about 135 C. The semi-fluid extrudate was immediately pressed in a continuous screw press to obtain high quality oil and press cake. Extrusion prior to expelling greatly increased the throughput of the expeller over the rated capacity. An oil recovery of 70% was obtained in single pass expelling using pilot model expellers. Higher recovery rates can be expected with commercial scale expellers. The high temperature-short time extrusion cooking process eliminates the prolonged heating and holding of raw material in conventional expelling. Under the experimental conditions, press cake with 50% protein, 6% residual oil and 90% inactivation of trypsin inhibitors was obtained. The low fat cake was easily ground in a hammer mill without the usual problems associated with milling of whole beans. The expelled oil was remarkably stable with an AOM stability of 15 hr, which is comparable to refined deodorized oil according to NSPA specifications. The new procedure offers potential for producing natural soybean oil and food grade low fat soy flour by a relatively low cost operation. It may be adopted as an improvement to existing conventional expelling operations in less developed countries or as a commercial or on-farm operation for producing value added products from soybeans within the U.S.

The purpose of this paper is to establish the new concept of coupling dry extrusion with mechanical expelling of oil from soybeans in order to obtain both oil and cake suitable for human food. The critical factor is to obtain a semi-fluid extrudate by appropriate extrusion conditions and to expell immediately, while the extrudate is still in the fluid state. While the preliminary results indicate that high quality oil and cake can be produced by the application of the new concept, additional work is needed to develop commercial reality. Further development of the concept and its scale up for possible application at the commercial level is being actively pursued. It appears that this technique should be suitable for use with other oil-bearing seeds.

Before the development of solvent extraction techniques, the oil extraction industry was based on mechanical methods such as hydraulic pressing and continuous screw pressing. Of 1.9 million tons of soybeans processed for oil in the U.S. in 1940/1941, 77% was extracted by mechanical methods (1). Although solvent extraction has replaced mechanical methods of oil extraction in the West, expeller processing remains a viable industry in other parts of the world. Soybean is a low oil-bearing material (18-20% oil) compared to some other sources, such as peanut (45% oil), coconut (55% oil) and palm kernel (55% oil). Regardless of the method of oil extraction, the oil expelling industry is geared to producing oil for edible and industrial purposes, while the spent cake is used predominantly for livestock feed. In recent times, great emphasis has been placed on the use of soybeans, not only for oil but also as a source of edible protein for human food. In the developing countries where this need is strongly felt, extraction of oil using continuous screw presses is widely used. When the press cake from oil milling is intended for human food, it is also important that the process must ensure adequate heat treatment of the cake in order to reduce the levels of anti-nutritional factors without protein damage. In conventional expelling, where maximum oil yield is the criterion of emphasis, it is not uncommon to make several passes through the expeller. While this increases oil recovery, it also results in excessive heating of the cake, resulting in a brown color and scorched flavor. Increased oil recovery is also accompanied by over-heating, darkening, and deterioration of oil.

In the native state, soybean oil is deposited within the bean tissue cells in bodies known as spherosomes (2). In conventional screw pressing operations, the beans are cracked and subjected to dry heating over a prolonged period of time so that the temperature of the material reaches 116-132 C and results in reduction of moisture to 2-5%. Low moisture is generally desired in commercial expelling operations (1). The heated material is held at high temperature for moisture equilibration before being fed into the expeller. The expeller performs two functions. First, it further disrupts the tissues and releases hot oil within the matrix. Second, it forces the oil out of the matrix under pressure.

Extrusion offers a convenient method of tissue disruption and heating by a single step, in a slight fraction of the time required for bean conditioning in conventional expelling. The residence time in the extrusion system used in this work is less than 30 sec, and the temperature of material is raised from ambient to 135 C. The high temperature, short time treatment contributes greatly to the retention of the nutritional value of the products. Low cost extruders, which generate heat by friction, eliminate the need for an external heat source.

Recent literature (3-5) indicates that extrusion enhances solvent extraction efficiency of various oil-bearing materials. The work reported here was carried out to investigate the feasibility of using dry extrusion as a pre-treatment to process soybeans into oil and food grade cake, using a mechanical method of extraction. Investigations described here were started in July 1985. Results obtained thus far indicate that dry extrusion of whole soybean under proper conditions and immediate expelling of the extrudate in a single pass through the expeller can produce high quality oil and excellent low fat cake ideal for food applications. The oil recovery rates reported here relate to the specific type of small pilot scale expellers used in this study, and in no way reflect the maximum possible recovery under commercial conditions. More work is under way to optimize the extrusion/expelling parameters as they relate to oil recovery and quality of cake. Further work on characterization of oil and specific food applications of the cake is needed.

MATERIALS AND METHODS

Soybeans of the varieties Century, Williams-82, and BSR-201 were used in these studies. Moisture contents were adjusted where necessary by adding the requisite water quantities to 23-kg batches of whole soybean, followed by thorough mixing. The beans were held overnight to equilibrate before processing. For purposes of extrusion, the beans were ground in a Bauer mill. The average particle size distribution of the ground soybean is given in Table 1. Extrusion was carried out in an INSTA PRO 2000-R extruder (Fig. 1) with a screw diameter of 13.2 cm and powered by a 75-hp motor. This extruder, with a motor RPM of 1725 and screw RPM of 550, has a rated capacity of approximately 680 kg/h. The estimated dwell time within the chamber was stated as 20-25 sec when using oilseeds. The extruder configuration was kept constant throughout the investigation. The extrusion temperature was controlled within limits by manipulation of feed rate, ground bean moisture content and back pressure on the die.

Initial studies on pressing of extrudate were carried out using a hydraulic press. For this purpose, a Carver press with a sample cylinder having a cross section area of 6.45 square cm was used. A constant gauge pressure of 705 kg/cm2 was applied to samples for one min. Three models of continuous expellers were used in subsequent experiments. Their specifications are shown in Table 2.

In the initial studies, the semi-fluid extrudate emerging from the die of the extruder under steady state was immediately filled into the sample cylinder and pressed in the Carver press. Several samples were taken from a given run, and the experiment was repeated over several runs. In the case of screw pressing, the extrudate coming out of the extruder was immediately and continuously hand fed to the press. Oil and cake were collected for analysis at intervals after the expeller was running hot and at a steady state. In the case of each model of screw press, the experiment was repeated over several runs on different days. All experimental results refer to a single pass through the expeller. A flow diagram of the process is given in Figure 2.

The raw material, extrudates, press cake and oil were sampled and held under refrigeration for analysis. The moisture content, protein, oil, and ash contents were analyzed by the appropriate AOAC (6) procedures. Total dietary fiber (TDF) was determined by combined enzymatic and gravimetric procedures according to Prosky et al. (7). The protein dispersibility index (PDI), peroxide value, free fatty acids, moisture and volatile matter of oil were determined according to AOCS (8) procedures. Trypsin inhibitory activity was determined according to Hammerstrand et al. (9). Oil recovery is reported in terms of the difference between the oil content of the feed and oil content of the press cake expressed as a percentage of the oil content of feed.

TABLE 1

Average Particle Size Distribution of Soybean Fed to the Extruder

Screen	%
On USS 14	7.7
On USS 20	22.2
On USS 40	32.0
On USS 60	34.4
Through USS 60	3.7
	100.0

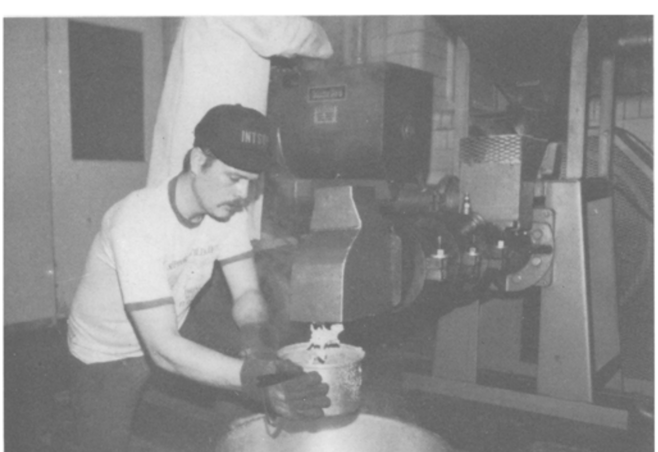

FIG. 1. The INSTA PRO 2000-R extruder.

TABLE 2

Specifications for Three Models of Expellers Used in Experiments

Model	Source	Rated capacity, cold pressing Whole grain kg/hr	L/D[a]
Mini-40	Simon Rosedowns, England	39	2.4
ZYB-78	China Machinery & Equipment Export & Import Corp.	39	4.1
ZX-10	China Machinery & Equipment Export & Import Corp.	150	5.1

[a]Length/diameter ratio of drainage barrel.

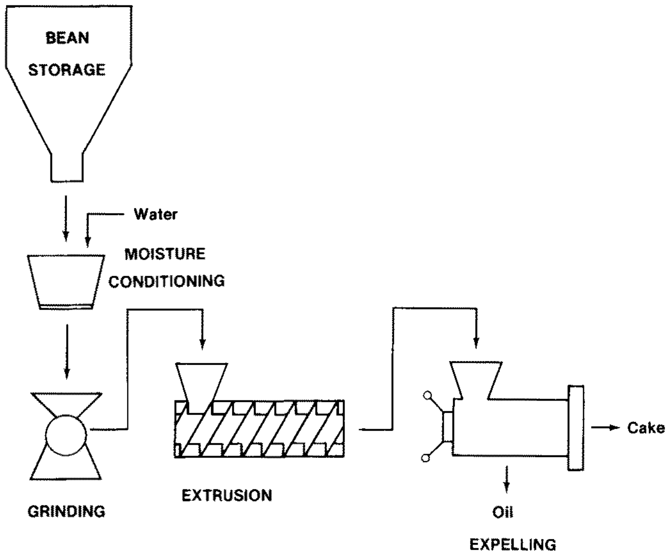

FIG. 2. Flowsheet for the coupled process of extrusion and expelling of soybeans.

RESULTS AND DISCUSSION

Extrusion. According to previous experience with the INSTA PRO 2000-R extrusion system, whole soybean could be extruded at moisture contents of 10-14%. The present study was carried out within this range of moisture levels. Each day, the extruder was started with whole soybeans fed with the synchronous feeder. Once the extruder temperature was raised to near operation temperature, the ground experimental material was fed from the side feeder at a controlled rate. The average particle size distribution of feed, ground through the Bauer mill, is given in Table 1. At the beginning of the run, the extrudate emerged from the die as an oily and granular mass. As the temperature was gradually raised, there was a point at which the extrudate flowed out of the die in the form of a viscous liquid. Presumably, the forces of shear and compression within the extruder distrupt the tissues and release the oil into the matrix. The high temperature reduces oil viscosity, resulting in the change of physical state. However, once the extrudate emerges, the fluid nature is rapidly lost and the mass becomes granular. Re-absorption of the oil into the matrix, drop in oil viscosity (due to drop in temperature), and flash evaporation of residual moisture may be factors contributing to the observed reversal of the physical state.

It is important to control extrusion parameters so that the extrudate emerges from the die in a semi-fluid state. The process parameters that affect fluidization are feed moisture, feed rate, pressure on the die, and the configuration of the extruder. It was possible to obtain fluidization of the extrudate over a range of temperatures by manipulation of the above process parameters. In general, fluidization occurred at extrusion temperatures above 121 C. However, the material tends to scorch when the temperature rises above 148 C.

The results of pressing the extrudate in the Carver Press immediately after emergence and also after cooling overnight are presented in Table 3. As the extrusion temperature increased from 107 to 141 C, the oil yield also increased when the extrudate was pressed immediately after emergence. At temperatures above 135 C (runs 4, 5, 6), where the material assumed a fluid state, there was a clear increase in the oil recovery rate as compared to the lower temperature range. Under the conditions of pressing used in the experiment, up to 69% of the original oil in feed was expelled. After the extrudates were left overnight and pressed under the same conditions, there was a drastic reduction of oil recovery in all cases regardless of the extrusion temperature. This demonstrated the need for expelling the oil immediately after extrusion, while the oil is still in a relatively free state. Based on these results, all subsequent experiments were carried out at extrusion temperatures between 135 and 140 C, making every effort to press the extrudate in the fluid state.

Trials with the Mini-40 oil expeller. The Mini-40 oil expeller is a bench model expeller having a rated capacity of 39 kg/hr. Other factors remaining constant, the efficiency of expellers is rated on the basis of length to diameter ratio (L/D) of the drainage barrel (10). The Mini-40 has a L/D ratio of 2.4. The pressure applied during expelling is read on a scale marked in arbitrary units on the screw locking device. Initial runs were carried out to study the effect of using whole beans and dehulled beans on the recovery of oil. The expeller

TABLE 3

Results of Pressing Hot and Cold Extrudates Using the Carver Press

		Oil recovery (%)		
Run[a]	Extrusion temperature, C	Hot extrudate	Cooled extrudate	Residual oil in hot extrudate cake (%)
1	107	57.8	45.6	9.5
2	127	56.3	51.8	9.7
3	132	60.7	50.3	8.6
4	135-141	65.5	46.1	6.7
5	135-141	66.3	54.5	5.7
6	135-141	69.0	47.6	5.8

[a]Figures for each run represent average of three or more determinations.

pressure was held constant at five units on the arbitarary scale. The results are given in Table 4. The apparent oil recovery, estimated from the difference in oil content between feed and cake, appeared to be higher for cotyledons than for whole beans. However, the oil expelled from the cotyledons carried more foots (fines in oil). When the oil recovery was corrected for foots, there was little difference between whole and dehulled raw material. It is likely that the presence of the hull results in a more porous matrix, allowing free flow of oil during expelling and resulting in less foots in the oil. It appeared from the results that the additional process of dehulling may not be warranted by the minimal increase in oil recovery over the whole beans. For the purpose of dehulling, the beans were heated in a Proctor Schwartz drier at 98 C for 20 min. This accounts for the lower initial moisture content in cotyledons as compared to the corresponding whole beans (Column 2, Table 4). With regard to initial moisture effects, it appears from Table 3 that for both whole beans and cotyledons there was higher oil recovery at the lower moisture level.

In the operation of the Mini-40 expeller, it was found that the whole soybean extrudate could be expelled at pressure settings up to 20. Higher pressures caused jamming of the screw. The pressure setting scale did not directly relate to a specific pressure developed in the expeller. It did, however, relate to the discharge opening space in the expeller which controlled the thickness of the cake as it left the expeller. A given setting always produced a cake of predictable thickness. As the discharge opening was reduced, the thickness of the cake was also reduced. Reduction of cake thickness certainly increased expelling pressure, but no actual readings could be made. Table 5 shows the results of expelling at four pressure settings in the practical range of operation. The process of extrusion reduced the moisture content of the material from 10.6% in the feed to 6.3% in the extrudate. Progressive application of pressure to the expeller resulted in the reduction of cake thickness and associated decrease in the residual oil content of cake. The manufacturer's specifications for the expeller indicated that under conventional extraction the residual oil content of the cake is expected to be 10-15%, depending upon the oil-bearing material. However, Table 5 indicates that by extrusion prior to expelling, it was possible to reduce the residual oil content of the cake to approximately 8.4% in a single

TABLE 4

Effect of Using Whole Soybeans and Dehulled Soybeans on Oil Recovery Using the Mini-40 Oil Expeller

Feed	Moisture content (%)	Oil recovery (%)	Foots in oil (%, w/w)	Oil recovery, corrected for foots (%)
BSR-201 (whole beans)	11.2	37.7	0.2	37.6
BSR-201 (cotyledons)	7.9	42.4	4.5	40.5
BSR-201 (whole beans)	9.4	39.2	0.2	39.1
BSR-201 (cotyledons)	5.9	43.8	4.3	41.9

Each value represents the average of duplicates.

TABLE 5

Effect of Pressure Setting on the Performance of the Mini-40 Expeller Using Whole Soybean Extrudate

	Run	Moisture (%)	Oil (%)	Oil recovery (%)	[a]Average cake thicknesses (cm)
Feed	1	10.59	20.28	–	–
	2	10.59	20.28	–	–
Extrudate	1	6.34	19.96	–	–
	2	6.34	19.96	–	–
Cake (pressure 5 units)	1	5.33	10.51	48.18	–
	2	6.01	10.28	49.31	2.67 ± 0.3
Cake (pressure 10 units)	1	5.72	9.45	53.40	–
	2	5.13	9.98	50.79	2.55 ± 0.3
Cake (pressure 15 units)	1	5.42	9.13	54.98	–
	2	5.39	9.27	54.29	2.16 ± 0.2
Cake (pressure 20 units)	1	5.04	8.44	58.98	–
	2	6.04	8.49	58.14	1.98 ± 0.1

[a]Mean ± standard deviation for 10 measurements.

TABLE 6

Performance of the ZYB-78 Oil Expeller Using Whole Soybean Extrudates

		Moisture content				
Run	Pressure	Feed to extruder (%)	Cake (%)	Oil in cake (%)	Oil recovery (%)	Average cake thickness (mm)[a]
1	6 threads	10.59	5.00	7.36	63.71	–
2	6 threads	11.05	4.46	6.50	67.94	–
3	6 threads	12.01	4.27	7.32	63.89	–
4	6 threads	12.01	5.57	7.28	64.12	2.88 ± 0.3
5	5 threads	11.00	3.63	5.92	70.79	2.59 ± 0.1
6	5 threads	11.02	2.41	5.34	73.69	–

[a]Mean ± standard deviation for 10 measurements.

pass. The maximum oil recovery obtained was 58.98%. In all cases, the residual moisture content of the cake was less than 6%, which is desirable for good keeping quality.

Trials with the ZYB-78 Chinese expeller. This expeller (Fig. 3) had a L/D ratio of 4.1 compared to 2.4 for the Mini-40 expeller and also a rated capacity of 39 kg/hr for cold pressing whole soybeans. There was no provision for measuring the pressure applied during operation. Therefore, the number of threads on the worm shaft that are exposed when the shaft is locked in place was used to set pressure (the greater the number of exposed threads, the lower the pressure applied). Two pressure settings with six and five threads exposed were used in the expelling of whole soybean extrudates. The results obtained over several runs are presented in Table 6. As expected from the L/D ratio, a higher oil recovery was obtained from this expeller than from the Mini-40. The maximum recovery at a pressure setting of six threads was 67.94%. As the pressure was increased to a setting of five threads, oil recovery in excess of 70% was obtained.

The expeller capacity was rated by the manufacturer at 39 kg/hr for cold pressing of soybeans. However, the actual throughput of the hot soybean extrudate under the conditions of our experiments was estimated at 125-135 kg/hr. Therefore, extrusion prior to expelling greatly increased the capacity of the expeller. The functions of grinding, heating and release of oil from the tissues already are performed by the extruder when the feed enters the expeller. The energy supplied to the expeller is used primarily for pressing the oil. This apparently is the reason for the increase in the throughput of the expeller over its rated capacity.

Trials with the ZX-10 Chinese expeller. This expeller was a larger model having L/D ratio of 5.1 and a rated capacity of 150 kg/hr for cold pressing. It had a provision for force feeding from a hopper by means of a vertical screw auger. The configuration of the worm shaft was different from that of the other two expellers. The continuity of the flight was interrupted by two flat zones which did not propel the product. This expeller did not perform satisfactorily for pressing the extruded soybean. The main probelm was the accumulation of oil in the barrel and back flow toward the feed end. The worm shaft assembly was dismantled and reassembled in different configurations in order to obtain more positive forward transport of the feed. The space between the cage bars was increased to facilitate the flow of oil out of the extraction barrel. These attempts were only partially successful. In five weeks of work with this expeller, only a few runs were made on a continuous basis without surging problems. These runs were of short duration and at a low feed rate of approximately 68 kg/hr. The results of expelling unextruded and extruded soybeans are given in Table 7. Even under sub-optimal conditions of expeller operation, 71.8%

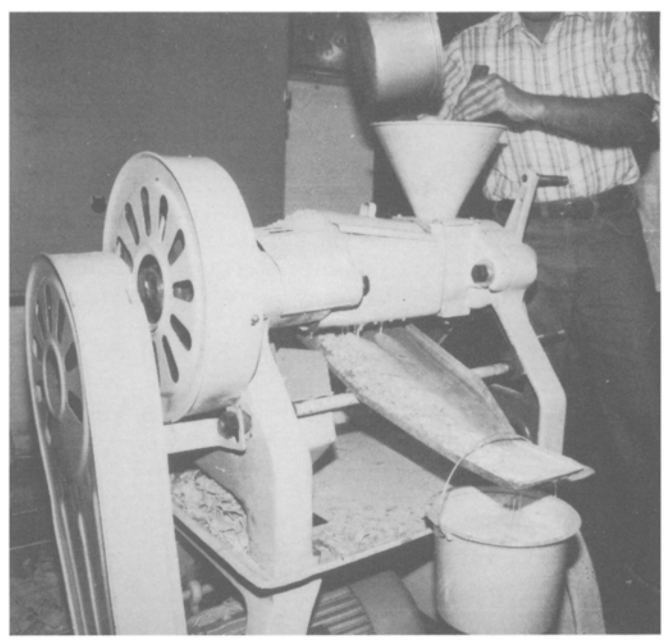

FIG. 3. The Model ZYB-78 Chinese oil expeller.

TABLE 7

Performance of the ZX-10 Expeller Using Whole Soybean and Extrudates

Feed	Feed (%)	Cake (%)	Oil in cake (%)	Oil recovery (%)
Ground whole soybean	10.01	8.26	7.76	61.2
Whole soybean extrudate	5.72	3.11	5.65	71.83

recovery was obtained from the extrudate. Much difficulty was encountered in passing unextruded material through the expeller. The 61% oil recovery from unextruded material as reported in Table 6 was achieved in one run which was accomplished with difficulty. From the experience with this expeller, it was apparent that a worm shaft with a continuous flight was necessary for satisfactory operation with soybeans, particularly after extrusion cooking of the feed prior to expelling. Therefore, the ZX-10 expeller was not used in further work.

The results of the pilot plant scale experiments with three different expellers amply demonstrate that over 70% of oil in whole soybeans can be extracted by extrusion prior to single pass expelling. The oil recovery obtained was subject to two limitations in our experiments. First, there was an unavoidable time lapse between the emergence of the extrudate and manual feeding of the extrudate to the expeller. It is expected that direct coupling of the extruder to the expeller (without heat loss from the extrudate) would result in a slightly higher oil recovery rate. Second, the oil recovery would be enhanced under commercial conditions of operation, using more efficient expellers, compared to the small scale, pilot type expellers used in the experiments.

Quality of cake. One of the objectives of this work was to produce a low fat cake of high quality, suitable for food use. In conventional multi-pass expelling operations, the material is subject to prolonged dry heating prior to and during expelling. This causes excessive heating and scorching of the cake. In the system described here, the extrusion process amounts to a high temperature short time heating, lasting less than 30 sec. Since expelling is limited to a single pass through the expeller, the possibility of scorching is very limited. However, it is imperative that the heat treatment should be adequate to reduce the antinutritional factors to acceptable levels to allow the cake to be used for edible purposes. Although the heat treatment in extrusion cooking is of short duration, it takes place under high temperature, high pressure and intimate mixing. The residual trypsin inhibitory activity and protein dispersibility index of press cake were used to determine the extent of heat treatment under the experimental conditions. Table 8 gives typical analytical data for raw material, extrudate and press cake. It is shown that 91% of the initial trypsin inhibitory activity of the raw soybean was destroyed by the extrusion treatment, and that the residual trypsin inhibitory activity in the press cake was only about 6% of the activity in the original raw material. Heat destruction of the antinutrients is associated with reduction of protein dispersibility index from 88% in the raw material down to 13% in the press cake. On a dry weight basis, the press cake at 6.62% oil had a protein content of 50% and total dietary fiber content of 19.4%. On visual observation, the ground raw material had a creamy yellow color. Upon extrusion, the color changed to light brown. However, after expelling of oil, the color of the cake improved and was not visually different from that of the raw material. The Hunter redness/yellowness index (Hunter a/b ratio) was reported to be highly correlated with visual color (11), lower values indicating increasing yellowness and vice versa. From Table 8, it can be clearly seen that the a/b ratio of raw material increases upon extrusion and that after expelling, the ratio approaches that of the raw material. The sensory quality of the cake was always excellent, being very bland and light in color.

Whole soybeans cannot be ground into flour by conventional dry milling equipment such as plate mills and hammer mills, because of the high oil content. Specialized equipment such as pin mills can be used to produce full-fat soy flour. However, the high cost of these grinding systems is a barrier against the production and use of full-fat soybean flour in less developed countries where the need is critical. The partially

TABLE 8

Analysis of Whole Soybean, Extrudate and Press Cake Obtained From the ZYB-78 Oil Expeller[a]

	Ground whole soybean	Whole soybean extrudate	Whole soybean press cake
Protein, %	41.94	42.62	50.14
Oil, %	20.28	20.95	6.52
Total ash, %	4.81	5.18	5.96
Carbohydrates, % (by difference)	32.97	31.21	37.38
Total dietary fiber, %	17.26	16.85	19.35
Trypsin inhibitors (mg/g defatted solids)	48.84	4.36	3.02
% destruction of trypsin inhibitors	0	91.07	93.82
Protein dispersibility index, %	88.38	14.99	12.65
Color, visual	Cream yellow	Light Brown	Cream Yellow
Color, Hunter a/b ratio	0.066	0.205	0.096

[a]Proximate constituents are reported on a dry basis.

TABLE 9

Characteristics of Expelled Soybean Oil Compared With NSPA Specifications for Commercial Grades of Solvent Extracted Soybean Oil

Factor	Expelled oil[a]	Prime crude oil[b]	Once refined oil[b]	Refined deodorized oil[b]
Moisture and volatile matter (max, %)	0.06	0.3	0.1	0.06
Free fatty acids (% as oleic acid)	0.19	–	0.1	0.05
Peroxide value (meqg/kg)	0.98	–	–	1.00
Unsaponifiable matter (%)	1.08	1.6	1.5	–
AOM stability (hours to attain 100 peroxide value)	15	–	–	15
Clear, brilliant	Yes	–	–	Yes

[a]Experimental values.
[b]NSPA specification.

defatted pressed cake, produced by extrusion of whole soybean and subsequent expelling, was found to grind satisfactorily in both the Bauer mill (plate mill) and the Micropulverizer (Hammer mill). The extruder performs the function of coarse grinding the feed; therefore, the power requirements for fine grinding of cake may become energy efficient. Further investigations will be carried out on grinding characteristics of the cake, keeping quality of the flour and its performance in various food systems.

Quality of oil. The oil flowing out of the expeller under the experimental conditions was at a temperature of 102-105 C. The hot oil was passed through a screen to remove the coarse foots, and the oil was allowed to stand overnight at room temperature for cooling and sedimentation. The clear, light-colored oil was then decanted, leaving the sludge. The oil was free of beany and grassy odors and had a slight nutty aroma. Results of oil characterization in relation to the National Soybean Producers Association (NSPA) trading specifications (12) are compared with crude, once refined and refined deodorized solvent extracted soybean oil in Table 9. The moisture and volatile matter content in expelled oil was better than the NSPA specifications for prime crude and once refined oil, and comparable to that of refined deodorized and partially hydrogenated oil. Free fatty acid content was higher than the specification for once refined oil and the peroxide value was comparable to the maximum specification for refined and deodorized oil. The AOM stability of expelled oil was remarkably high and met the minimum specification for refined and deodorized oil. The stability of oil is probably due to the naturally present antioxidants in soybeans, such as the tocopherols.

Food use of vegetable oils with little or no refining is common in developing countries. The expelled oil also could be considered a natural product for the health food market. Many samples of oil were held in partially filled bottles for as long as one year at room temperature without developing any rancid odor. Since expelled soybean oil had good stability, it may have considerable potential as edible oil without further refining. The nature and extent of non-lipid components extracted with the oil under extrusion and expelling conditions and the performance of the oil and cake in specific food applications will be evaluated by further investigation.

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