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Belize Commercialization of Alternative Crops Project
A USAID-Financed Project

ECONOMIC EVALUATION OF SOYBEANS AND SESAME

IN BELIZE

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BABCO

A private non-profit organization dedicated to the development of technology in the production, marketing and processing of non-traditional crops for export and import substitution in Belize.

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SUMMARY

For the most part, oilseeds have not been produced in Belize. However, CARDI commenced oilseed trials in recent years and has confirmed that soybeans and sesame can be grown successfully. During 1987, on-farm soybean trials and sesame trials were conducted by CARDI for BABCO under the auspices of the Commercialization of Alternative Crops Project.

Sesame will probably be grown by small farmers for the domestic market. Processing is not required. The cost of production is approximately BZ 46 1/2 cents per pound and the selling price for small quantities has ranged from BZ 70 cents to BZ$ 1.00. Recent prices of BZ 45 to 48 cents for Mexican production CIF the Port of Houston would prevent Belize from participating in the US market at this time.

December 1987 soybean plantings of on-farm trials are progressing. A 50-acre crop at CARICOM Farms is progressing. Plantings in June with harvest in October are expected to yield higher than the December plantings with harvest in April. June 1987 on-farm trials averaged 1,869 pounds per acre. Much depends on weather; however, CARDI believes 2,000 pounds on-farm average commercial production per acre can be achieved. In this study, 1,800 pounds per acre is used, and the on-farm plot cost of production, where 1,800 pounds or more per acre was produced, was BZ 25.9 cents per pound.

The larger farmers with farm machinery, particularly self-propelled combines for harvesting, would be the probable soybean producers in Belize. CARDI estimates that large farmers would plant and harvest 30 to 40 acres each. With experience, these farmers would likely produce soybeans for less than BZ 25.9 cents per pound.

A soybean processor could pay the farmer BZ 33 to 35 cents per pound delivered for soybeans at this time and realize a processing profit by substituting either full-fat or low-fat soybean meal for imported concentrate in feed rations.

Poultry is the most popular meat, and poultry feed for the production of meat and eggs represents the largest demand for soybean meal in Belize. Pork production is the next most important demand.

There is an immediate potential for more than 3,000 acres of soybeans to meet the indicated demand for soybean meal to be utilized in poultry and pig feeds. When experience is gained in the production of soybeans; soybean processing; reformulation and substitution of concentrate with locally produced soybean meal, there is a potential demand for 5,213 to 6,006 acres of soybeans, depending on the method of processing.

In 1986, 11,494,762 pounds of concentrate was imported and mixed with locally produced grains for the production of feed for poultry and pigs in Belize. Between 80% and 90% of the protein in the concentrate could be replaced by soybean meal produced in Belize.

The price of concentrate has advanced from about BZ 31 cents to a range of BZ 42 to 45 cents per pound since 1986. The increase reflects the price rise of the principal ingredient, soybean meal. Concentrate is duty-free, but there is a possibility that a duty will be established at the May 1988 meeting of CARICOM States on Common External Tariffs. In this event, the cost of concentrate will increase even more.

There is a significant profit potential for the soybean farmer and the soybean processor. The production and utilization of soybeans in Belize should reduce feed ingredient costs, resulting in reduced livestock and poultry production costs and the cost of meat to consumers.

The establishment of a soybean processing facility should be encouraged in Belize for the production of full-fat soybean meal. Oil extraction and the production of low-fat soybean meal is a viable option now, or at a later date. Simple, cost-effective soybean processing methods are commercially available for developing countries.

The substitution of imported concentrate with locally produced soybean meal would have the following economic effect on Belize:

	BZ$ Full-Fat Meal Production	BZ$ Low-Fat Meal Production
Substitution of -		
9,195,810 lbs concentrate @ BZ 42 cents/lb	3,862,240	3,862,240
1,405,378 lbs oil @ BZ 78 cents/lb	- 0 - 0 -	1,096,195
Foreign exchange savings	3,862,240	4,958,435
Farm income increase	3,096,548	3,567,498
Farm labor earnings increase	622,484	717,176
Processing labor increase	25,000	25,000

BACKGROUND

Belize is a small Central American democracy and a member of the CARICOM Community. The population of Belize is about 165,000. Land is the country's most important natural resource. Commercial agriculture is relatively new in Belize, but even so agriculture represents about 16% of the Gross Domestic Product (GDP) (p. 21). The primary crop is sugar cane with sugar representing 43% of the nation's exports in 1986 (p. 22). Costs of production for many agricultural commodities are high in Belize compared to other developing countries in Central America and the Caribbean. Costs of labor and utilities are higher than in surrounding areas.

As a member of CARICOM, Belize is bound to maintain uniform duties on imports from non-CARICOM countries and to permit imports from CARICOM members duty free. CARICOM members, however, have very little that is needed by other CARICOM members, and reliable shipping between CARICOM countries frequently prevents trading. Unfortunately, CARICOM protective import duties result in high production costs that contribute toward making CARICOM member states non-competitive with the rest of the world. Import duty rate increases are under review at this time and are expected to be increased significantly when the CARICOM meeting on Common External Tariffs is held during May 1988.

Belize does not have metals, coal, oil, or other economically recoverable resources. Belize is almost totally dependent on imported petroleum for energy. Electricity is produced by diesel powered generators with the exception of one hydroelectric plant built by Mennonites on the Mexican border. This dependence on imported petroleum results in extremely high costs for electricity. The electric rate for home and industry is BZ 41 cents (US 20.5 cents) per KWH. This is approximately four times the US 5 cents per KWH industrial rate in many parts of the US.

The price of gasoline is BZ$ 3.52 (US$ 1.76) per gallon. Much of the fuel price is the result of a high import duty on petroleum products. The duty is to discourage the non-essential use of fuel. At the same time, it is an essential source of revenue for the GOB.

The high cost of energy is perhaps the most important factor that results in Belize's being a high-cost manufacturer as well as a high-cost producer of agricultural products. Even farm labor and common labor at BZ$ 2 per hour (US$ 1) is expensive compared to labor costs in surrounding countries.

Also adding to the high-cost structure in Belize is the small quantity purchases of imported items for a small

population. This prevents Belize from enjoying the benefits of the economy of scale in purchasing even essential items. The shallow port at Belize City can accommodate only small vessels with high freight costs. The same is true for exports.

Until the early 1930's, Belize (then British Honduras) was a country engaged in exporting mahogany wood products. Small home gardens and citrus groves were maintained principally for home use. The supply of logs diminished, and Belize was forced to seek alternative sources of income.

When Great Britain acquired logging rights in the country from Spain in the early 1800's, the agreement was that there would be no British permanence established in the area and that agriculture would not be encouraged. In fact, it appears that agriculture was discouraged, and even food for slaves was imported. Sometime during the 1800's, Great Britain gave British Honduras the status of a colony. Sugar cane production was encouraged to the extent that it could supply in-country demand. Later, a sugar import quota of about 2,000 tons to Great Britain was obtained, and a sugar mill was established.

Outside capital encouraged a copra industry, but that venture failed as a result of a disease in the coconut plants. Again, outside capital started a citrus industry, which is in operation. Citrus concentrate and essential oils from grapefruit and orange rinds are being exported.

The worldwide glut of sugar and the constant threat of sugar quota reductions by the US puts Belize in a vulnerable foreign exchange position.

There is the realization by Belizeans that exports will be slow to increase and that the in-flow of foreign exchange will likewise be slow to increase. Urgent attention is being given to the production of Belizean commodities having the potential for import substitution to stem the out-flow of foreign exchange.

The Commercialization of Alternative Crops Project (CAC) was initiated in June 1986 by the Ministry of Agriculture and the United States Agency For International Development (USAID). The Belize Agri-business Company (BABCO), a non-profit organization, is responsible for administering the CAC Project until June 1990.

Briefly, the purpose is to restructure the agricultural sector to reduce its dependance on sugar. Alternative crops such as cucumbers, squash and papayas are being grown for the export market.

At the same time, ways are being examined to grow and process more agricultural commodities for the local market to replace imports. Soybeans and sesame are among these products.

1. CAN SOYBEANS AND SESAME BE PRODUCED IN BELIZE?

Belize has a total of more than 5.8 million acres, of which 2.1 million acres are considered to be agricultural land and only about 15%, or 315,000 acres, is being utilized. There is not a problem with the availability of tillable land, particularly for the small acreage anticipated at this time.

Oilseeds do not have a long history in Belize. However, CARDI field trials during recent years show that soybeans and sesame can be grown. During 1987, on-farm sesame and soybean trials were conducted by CARDI for BABCO under the auspices of the Commercialization of Alternative Crops Project.

Sesame on-farm trials have confirmed that the crop can be grown in Belize. Seven sesame plots (1.38 acres) were planted in December 1986 and January 1987 in the districts of Corozal and Cayo. Six trials (1.25 acres) were actually harvested in 1987. Yields ranged from 480 to 1,520 pounds per acre equivalent. The weighted average yield for all plots harvested was 806 pounds per acre. The average cost of production was about BZ 46 1/2 cents per pound. The average cost per acre for the harvested trials was BZ$ 375. Based on an estimated value of BZ 55 cents per pound, break even production would be 682 pounds per acre (p.24).

FAO Production - 1985 shows 1985 per acre production in the larger producing neighboring countries to be as follows: El Salvador 743 pounds; Guatemala 743 pounds; Honduras 839 pounds; Mexico 471 pounds. CARDI expects average yields of 700 to 1,000 pounds per acre.

For soybeans in Belize, the plantings have been in June with harvest in October, and plantings in December with harvest in April. A 50-acre soybean crop at CARICOM Farms was harvested in October, 1987. There were harvesting problems, but the yield was still 1,500 pounds per acre. Another 50-acre crop was planted in November 1987 and is progressing well with harvest expected in late March or early April, 1988.

Seventeen on-farm trials (11.18 acres) in total were initiated in Cayo, Corozal and Orange Walk Districts in 1987. Thirteen trials (9.18 acres) were harvested for the production of 16,054 pounds. Soybean yields averaged 1,869 pounds per acre in the CARDI/BABCO on-farm trials during 1987. The average cost of production was BZ 31 cents for all soybean crops harvested. The average cost of production at six on-farm trials that exceeded 1,800 pounds per acre was BZ 25.9 cents per pound (pp. 25, 26).

Based on the current soybean price of BZ 33 cents per pound, 1,467 pounds production per acre would be required to break even. This compares to the US average cost of production of BZ 17.6

cents in 1983; BZ 16.4 cents in 1984; BZ 12.8 cents in 1985. Again, the primary difference in the US cost of production was the yield per acre. The US comparison of production costs for soybeans was obtained from Economic Indicators of the Farm Sector, Cost of Production, 1985, USDA, ERS. The average US yields per acre were 1,543 pounds in 1983; 1,652 lbs in 1984; 2,007 in 1985. However, yields of 2,700 pounds per acre and higher are quite common.

CARDI believes the farmers in Belize who grow soybeans will be relatively large farmers who have machinery, particularly self-propelled combines. Further, they believe the typical farmer will plant 30 to 40 acres.

For the purpose of this study, it is assumed that soybean yields in Belize should be in the area of 1,800 pounds per acre to be profitable for the farmer. However, large, experienced, mechanized farmers will probably produce soybeans at a lower cost and realize a profit with lower yields.

2. WHAT IS THE DEMAND FOR SOYBEANS AND SESAME IN BELIZE?

Sesame and soybeans are entirely different types of oilseed crops. Sesame has a distinct advantage over soybeans in Belize because processing is not required. Unprocessed sesame is used in confectionery products and in baked goods. Sesame is produced in neighboring countries and is known in Belize. Small quantities of sesame produced at on-farm test plots were sold at prices ranging from BZ 70 cents to BZ$ 1.00 per pound. Sesame is not a traditional Belizean crop; however, there is a potential domestic market for the unprocessed seed to supply the small population of Belize.

The unprocessed export market is large; however, sesame prices have recently been depressed. The recent CIF price at the Port of Houston was US$ 500 to 525 per metric ton, or BZ 45 to 48 cents per pound. FAO TRADE -1985 shows North and Central America sesame exports/imports and US imports as follows:

Metric Tons	1983	1984	1985
No. & Central Am. Imports	42,231	36,759	37,330
No. & Central Am. Exports	41,341	90,282	61,564
US Imports	42,787	36,759	37,330

The US is about the only market in the region for exports from Central America and Mexico. An informed source confirms the US market is not growing as indicated by recent US imports.

As a last resort, sesame could be processed by roasting or extrusion for livestock and poultry feeding as full-fat sesame meal, or mechanically screw-press extracted for the production of sesame oil and low-fat sesame meal. However, sesame would not compare favorably on a per acre basis with soybeans for this purpose. Assuming mechanical screw-press extraction were used, one acre of land in Belize would be expected to produce:

All in pounds	Sesame	Soybeans
Seed produced per acre	800	1,800
Oil produced per acre	312	234
Meal produced per acre	472	1,530

Sesame meal is a high-quality meal, and the amino acid profile blends well with soybean meal. In the US, the recent sesame meal price was about 75 to 30% of the soybean meal price.

Trade Reports (Belize) do not specifically list sesame oil as an imported product for Belize. Soybean oil and soybean oil based products (margarine, shortening, cooking and salad oils) are imported in significant quantities and are well known in Belize.

Soybeans must be processed in order to be utilized. Usually soybeans are processed for the production of soybean oil and soybean meal. Soybeans are the world's most important source of vegetable oil for the production of salad oils, cooking oils, margarine and shortening. Soybean meal is the most important source of protein in livestock and poultry feeds for the production of meat, eggs and milk.

If not processed for the production of oil and meal, soybeans must be subjected to high temperature to deactivate the anti-nutritional substances present in raw soybeans.

Production of soybeans in Belize will be limited to the quantity that can be utilized within the country. Being a high-cost producer, Belize cannot compete in world markets. There is a relatively large solvent soybean processing plant in Jamaica, a CARICOM nation, that would prevent Belize from competing, even in CARICOM.

SOYBEAN OIL DEMAND FOR IMPORT SUBSTITUTION

Assume, as an extreme example, the import substitution of the average imports for 1979-80 and 1985-86 of 5,745,606 pounds of vegetable oils, vegetable oil products, lard and butter being replaced by refined soybean oil produced in Belize (pp. 28, 31):

> 5,862,863 lbs of crude oil would be required to produce 5,745,606 lbs of refined soybean oil.
>
> At a 13.0% oil yield, using mechanical screw-press extraction, 45,098,948 lbs of soybeans would be required to yield 5,826,863 lbs of crude oil.
>
> 45,098,948 lbs of soybeans @ 1800 lbs yield per acre would require 25,055 acres.
>
> Processing 45,098,948 lbs of soybeans would yield 38,334,106 lbs of low-fat soybean meal.

This quantity of meal could not be completely utilized in Belize for livestock feeding, and the cost of production of the meal would prevent export in world market competition.

SOYBEAN MEAL DEMAND FOR POULTRY FEED IMPORT SUBSTITUTION

The poultry business in Belize is an efficient, integrated operation complete with breeder flocks, hatcheries, broiler growing houses, feed mills, dressing plants, marketing and distribution. The business is almost entirely in the hands of Mennonites. Mennonites deliver fresh broilers to restaurants and retail shops twice a week throughout most of the country. The reported 1984 per capita consumption of commercially produced broilers was about 41.7. This figure has increased since then.

Many urban residents and most rural residents have a few chickens; however, this is usually for home consumption. About 47,000 chicks from Mennonite hatcheries are placed weekly by Mennonites, and nearly the same number of chickens are dressed weekly at Mennonite poultry dressing plants. This amounts to about 2,444,000 broilers being sold annually.

Assuming a dressed weight of three pounds each, this amounts to about 7,332,000 lbs of chicken. The average import of whole chickens and other poultry for 1985 and 1986 was 112,895 pounds. This puts estimated consumption at about 45 pounds per capita at that time. This is in addition to the consumption from household flocks and culls from the breeder flocks and layer flocks. The total per capita consumption could be about 50 pounds in 1988, compared to US consumption of 72.9 pounds in 1986 and estimated consumption of 78.6 pounds in 1987. It has been

PROCESSING METHODS

Solvent extraction is the most common method of soybean processing in the world. A petroleum product, hexane, is used to extract the oil, and the residual oil remaining in the meal is normally not more than 1%. Even the smallest commercially available solvent extraction plant with a capacity to process 100 tons of soybeans per day is too large, too capital intensive and is not cost effective for many small, developing countries.

INTSOY researchers at the University of Illinois have examined several small, simple, low investment cost methods of soybean processing for soybean utilization in developing countries.

No Oil Extraction

Simple processing methods to deactivate the anti nutritional substances in raw soybeans, without extracting the oil, are available. Both methods involve the heat treatment of soybeans. Roasting is the least expensive method; however, mechanical extrusion is the recommended commercial method for Belize because it would produce a nutritionally superior product.

The equipment cost of the extruder and auxiliary equipment would be approximately US$ 35,000.

Oil Extraction

The extruder would serve as a conditioner for the mechanical screw-press extraction of oil in the event it is decided at the outset, or at a later time, to extract oil. Mechanical screw-press extraction is being utilized in many developing countries. This method removes most of the oil; however, the residual oil remaining in the meal is normally 5% to 6% of the weight of the low-fat meal. This method is described in the University of Illinois publication, Dry Extrusion as an Aid to Mechanical Expelling of Oil From Soybeans (pp. 35 - 41)

The cost of the extruder and auxiliary equipment (same as above), plus the cost of the mechanical screw press, would be approximately US$ 64,000.

Either of these alternatives would be cost effective and could be sized to provide ample capacity to process the soybeans produced on 2,000 to 6,000 acres in Belize.

RECOMMENDATION:

SESAME

Sesame on-farm trials should be continued because it appears the crop can be grown successfully by small farmers. CARDI believes the growers will be small farmers who have the potential to earn more by producing sesame than by producing corn.

The milpa (slash-and-burn) farmers would fit into this category along with other small farmers who have a very limited number of alternative crops. Sesame is a labor-intensive crop. According to BABCO, sesame required 103 hours of labor per acre and represented 55% of the costs of production. Small farmers would utilize family labor and make minimum cash inputs.

Sesame is a traditional crop in neighboring countries, and there is a domestic demand for sesame seed in Belize. Processing is not required. Unprocessed sesame has recently been sold for as much as BZ$ 1.00 per pound in the domestic market. Potential selling prices are two to three times the indicated value of soybeans grown in Belize, and this makes sesame seed too valuable for livestock feeding.

RECOMMENDATION:

SOYBEANS

The establishment of a private sector soybean processing facility should be encouraged in Belize initially to produce full-fat soybean meal for the import substitution of feed concentrate.

It has been demonstrated that soybeans can be produced at a cost of approximately BZ 26 cents per pound. Experienced, well equipped farmers would be expected to produce soybeans at a lower cost. Large farmers can be expected to accept a lower cash return per acre, and realize a profit on volume.

Soybeans could be sold at this time for BZ 33 to 35 cents per pound.

The initial goal should be to harvest and process 2,000 acres of soybeans in Belize. This acreage should provide the approximate quantity of soybeans required to produce the tonnage of either full-fat or low-fat soybean meal for the import substitution of concentrates as estimated by Mr. Reimer.

The production of 2,000 acres of soybeans should produce the approximate quantity of soybeans to closely match the 700-pound-per-hour capacity of a small extruder. A larger model extruder is available with the capacity of 1,800 pounds per hour.

On-farm trials and increased acreage should be encouraged. The growing and harvesting of 2,000 acres of soybeans would be a major undertaking in Belize. A soybean processor should be granted permission to import soybeans for an infant industry, duty free, for a period of time until local production can be assured. Present duty on soybean imports:

On CIF Value	Caricom Countries	Non-Caricom Countries
Stamp	12%	12%
Duty	0%	12%
Total	12%	22%

The Wall Street Journal (January 11, 1988), (p. 23) shows the recent cash price of soybeans in Central Illinois was BZ 20 cents per pound, and the price a year ago was BZ 16 cents per pound. Soybeans are normally handled in bulk, but would probably have to be bagged for this purpose.

After experience is gained in processing and reformulation, screw-press oil extraction should be added. It would be a major undertaking for management to make all of the potential changes at one time.

estimated that Belize has the sixth highest per capita poultry consumption of all countries in the world.

The delivered wholesale price of broilers has advanced recently from BZ$ 1.42 to BZ$ 1.50 per pound. This reflects the start of a seasonal increase in the price of corn and continued strong imported concentrate prices. The wholesale price of broilers has in the past been as high as BZ$ 1.65 per pound during periods of high demand vs inadequate supply. The retail price has recently been BZ$ 1.90 per pound.

In 1980, 44.7% of the average Belizean household's expenditure was for food. The consumption of chicken and poultry can be expected to continue to rise because Belizeans like chicken, and it is the least expensive meat in Belize.

REIMER FEED SHOP SOYBEAN MEAL DEMAND FOR IMPORT SUBSTITUTION

Mr. Otto Reimer of the Reimer Feed Shop at Spanish Lookout, is unquestionably the best judge of the current potential demand for full-fat soybean meal in Belize. Mr. Reimer has approached the demand of the Reimer Feed Shop as follows:

1. Super Broiler Chow - 42% protein with 7.5% fat. Imports 2,030,950 lbs. Assuming 80% replacement with full-fat meal = 1,624,760 lbs of meal #

   With a 98% full-fat meal yield from soybeans and a yield of 1,800 lbs of soybeans per acre, 921 acres required*

2. Broiler Chow - 48% protein with 3.5% fat. Imports 2,215,250 lbs. Assuming 80% replacement with full fat meal = 1,762,200 lbs of meal #

   With a 98% full-fat meal yield from soybeans and a yield of 1,800 lbs of soybeans per acre, 1,005 acres required*

Total	3,396,960 lbs of meal #	1,926 acres required*

Mr. Reimer's estimate indicates that 3,396,960 pounds of full-fat soybean meal could be substituted in two concentrate products used by the Reimer Feed Shop. Nearly 2,000 acres of soybeans would be required to meet Reimer's demand for full-fat meal. Conceivably, since Reimer Feed Shop is 60% of the market, the current soybean acreage requirement for the production of full-fat meal could be approximately 3,200 acres for Belize.

If the Reimer Feed Shop demand of 3,396,960 lbs of meal were met with low-fat meal produced by mechanical screw-press extraction, on a pound-for-pound substitution basis, 3,996,423 pounds of soybeans would be required (2,220 acres) and 519,535 pounds of crude oil would be produced.

SOYBEAN MEAL DEMAND FOR IMPORT SUBSTITUTION

The principal ingredient in concentrates is soybean meal produced by solvent extraction. The residual oil (fat) content of the solvent extracted meal is normally not more than 1%. Additional ingredients may include fish and/or animal protein, other vegetable proteins, vitamins, minerals, antibiotics and, perhaps some added fat.

	Concentrate Formula Range
48 % Protein Soybean Meal	80% - 90%
Other protein, i.e., fish, animal, etc.	10% - 0%
Vitamins, minerals, antibiotics, etc.	10% - 10%
Total	100% - 100%

These proprietary concentrate products are computer formulated to be mixed with locally produced grains to produce the least-cost, nutritionally complete feeding ration. Several concentrates are formulated to be used for optimum performance at various stages of livestock and poultry growth.

The full-fat soybean meal produced in Belize by either roasting or extrusion would contain about 17% to 19% oil (fat). Low-fat soybean meal produced by extrusion followed by mechanical screw-press extraction would contain 5% to 6% oil (fat). Full-fat soybean meal has been substituted (with the addition of vitamins and minerals) pound-for-pound for all of the imported concentrate in Broiler Starter, and has been substituted pound-for-pound for 1/3 of the concentrate in Broiler Finisher by CARDI in feeding trials. CARDI reports very satisfactory results in feeding these rations to broilers on an experimental basis.

Full-fat or low-fat soybean meal produced in Belize would replace all of the soybean meal in the concentrate and probably all of the fat. Soybean meal represents a significant share (up to 90%) of concentrate formulas and varies according to the intended use of a particular concentrate. Mr. Otto Reimer (p. 11) estimated that 80% of Super Broiler Chow and 80% of Broiler Chow could be replaced with full-fat soybean meal.

Full-fat or low-fat soybean meal would be used in poultry rations in the US if these products could be priced competitively in least-cost formulations. Soybean oil is more valuable than alternative sources of animal fat in the US.

Approximately 80% to 90% of the concentrate would be replaced by either full-fat or low-fat soybean meal. Eventually, up to 10% of the concentrate could be replaced by either fish meal, poultry by-products or animal by-products that could potentially be produced in Belize.

Approximately 10% of the concentrate consisting of vitamins, minerals, antibiotics, etc., would not be replaced. There are packaged commercial premixes available containing these essential ingredient items for a variety of poultry and livestock feeding programs.

The concentrate supplier would initially be requested to reformulate the concentrate to accommodate the locally produced full-fat or low-fat meal in addition to the locally produced grain.

RECAP OF LIVESTOCK DEMAND FOR IMPORT SUBSTITUTION

Belize imported an average of 24.5 lbs of meat and meat products per capita for 1985 and 1986 (p 29).

Chickens represent the largest demand for soybeans in Belize. Each pound of chicken produced represents nearly a pound of soybeans in the ration. The Reimer Feed Shop demand represents nearly 2,000 acres of soybeans.

Pork is thought to represent the second largest demand for soybeans grown and processed in Belize. Each pound of pork produced represents a potential market for about a pound of soybeans. The 1986 requirement of full-fat soybean meal for pork production in Belize would have required 583 acres of soybeans. Pork production is expanding rapidly.

On the basis of pork import substitution (excluding lard) for 1986, 1,216 acres of soybeans would be required to furnish the full-fat meal for equivalent pork production in Belize.

Belize has the immediate potential to utilize the production of soybeans from more than 3,000 acres.

Belize imported 11,494,762 pounds of concentrate in 1986 for poultry and swine feeding. Assuming 80% substitution, the full-fat requirement would be 9,195,810 pounds. Estimating a full-fat meal yield of 98%, 9,383,479 pounds of soybeans would be required. With a soybean yield of 1,800 lbs per acre, the acreage required would be 5,213 (pp. 27, 30).

On the basis of mechanical screw-press extraction, the requirement for soybeans would be 10,810,600 pounds to produce 9,195,810 pounds of low-fat meal, assuming a yield of 85%. This would require 6,006 acres of soybeans at a yield of 1,800 lbs per acre. In this scenario, there would be 1,405,378 pounds of crude soybean oil produced at a 13% oil yield.

3. WHAT IS THE POTENTIAL VALUE OF SOYBEANS GROWN IN BELIZE?

A commercial market has not evolved for the small quantity of soybeans grown primarily at on-farm test plots at scattered locations in Belize. There are no oilseed processing facilities because oilseed crops have not been grown in Belize. A market is not expected to develop until there is an effecient and profitable way to process and utilize an oilseed crop.

Obviously, the value of full-fat or low-fat soybean meal would be equal to the cost of the concentrate when replacing on a pound-for-pound basis.

The delivered port cost of the imported concentrate during 1986 was BZ$ 608 per short-ton as shown in the TRADE REPORT - 1986. The price of the principal concentrate ingredients, soybean meal, has advanced about 36% during the past year. The cash price of a short-ton of soybean meal at Decatur, Illinois, on 6 January 1988 ranged from US$ 201-204, and on 7 January 1988 ranged from US$ 196-199 (p. 23). The average was about US$ 200 compared to the depressed price of US$ 147 per short-ton a year earlier, an increase of 36% in market price. This increase has been reflected in the price of imported concentrates. The price of 48% protein concentrate was about BZ 37 cents in February 1987, and the most recent shipment cost BZ 41 to 42 cents, which correlates with the increase in the soybean meal price. Current replacement cost ranges from BZ 43 to about 45 cents per pound.

Concentrate is now duty free; however, the cost of imported concentrate may be increased even more by the amount of duty likely to be imposed at the meeting of CARICOM Ministers which is scheduled for May 1988. The agenda for the meeting will be Common External Tariffs.

The processor would be able to profitably substitute full-fat or low-fat soybean meal for up to 90% of concentrates now being imported.

Soybean prices in Belize would be expected to fluctuate with the price of imported concentrate and soybean meal if full-fat meal were produced. If low-fat meal were produced, soybean prices in Belize would tend to be influenced by the world price for soybeans, soybean oil and soybean meal.

Soybean prices, ranging from BZ 30 cents to 40 cents per pound, delivered to the processing location have been used to estimate the cost to produce full-fat soybean meal in Belize. At the current soybean price of BZ 33 cents per pound, the cost of full-fat meal would be as follows:

BZ$ per pound	Variable Cost	Plus Overhead	Total
Roaster using electricity & gas	.3477	.0092	.3569
Extruder using electricity	.3697	.01	.3797
Extruder rental tractor PTO	.3842	.01	.3942

(pp. 32, 33 and 34)

In many countries, there is a market price for soybeans; a market price for meal; and a market price for oil. The difference between the combined value of the two products, oil and meal, and the price of soybeans is called the gross processing margin. Here is an example:

Product	Yield	X Price	=	BZ$ Value/CWT	
Oil	13%	.75	*	9.75	
Meal	85%	.42	**	35.70	
Gross product value				45.45	
Delivered soybean cost				(33.00)	12% moisture
GROSS PROCESSING MARGIN				12.45	
Less processing cost				(3.55)	
Contribution to overhead and profit				8.90	

It appears the gross processing margin in Belize for low-fat meal production and oil extraction would currently be in the area of BZ 12.45 cents per pound. The break-ever soybean cost for the soybean processor would be about BZ 41.6 cents per pound.

* Oil price is estimated. The price of lard delivered port is BZ 78 cents; wholesale BZ 84 cents; retail BZ 97 cents. The retail price of refined and bottled soybean oil at a store in Orange Walk Town is BZ$ 2.375/lb. (The same oil, also in a plastic bottle, in a US retail store is selling for BZ$ 1.39/lb.) The oil resulting from mechanical screw-press extraction would be natural, filtered, crude soybean oil. There are no refining facilities in Belize. This type of oil is consumed in many developing countries. In the US, this oil is often called cold press oil and is sold in specialty food stores and health food stores. It foams when used in deep fat frying.

** Meal price is based on recent cost of imported concentrate, assuming pound-for-pound replacement of the soybean meal portion of the concentrate is with low-fat meal produced in Belize.

PROCESSING METHODS

Solvent extraction is the most common method of soybean processing in the world. A petroleum product, hexane, is used to extract the oil, and the residual oil remaining in the meal is normally not more than 1%. Even the smallest commercially available solvent extraction plant with a capacity to process 100 tons of soybeans per day is too large, too capital intensive and is not cost effective for many small, developing countries.

INTSOY researchers at the University of Illinois have examined several small, simple, low investment cost methods of soybean processing for soybean utilization in developing countries.

No Oil Extraction

Simple processing methods to deactivate the anti nutritional substances in raw soybeans, without extracting the oil, are available. Both methods involve the heat treatment of soybeans. Roasting is the least expensive method; however, mechanical extrusion is the recommended commercial method for Belize because it would produce a nutritionally superior product.

The equipment cost of the extruder and auxiliary equipment would be approximately US$ 35,000.

Oil Extraction

The extruder would serve as a conditioner for the mechanical screw-press extraction of oil in the event it is decided at the outset, or at a later time, to extract oil. Mechanical screw-press extraction is being utilized in many developing countries. This method removes most of the oil; however, the residual oil remaining in the meal is normally 5% to 6% of the weight of the low-fat meal. This method is described in the University of Illinois publication, Dry Extrusion as an Aid to Mechanical Expelling of Oil From Soybeans (pp. 35 - 41)

The cost of the extruder and auxiliary equipment (same as above), plus the cost of the mechanical screw press, would be approximately US$ 64,000.

Either of these alternatives would be cost effective and could be sized to provide ample capacity to process the soybeans produced on 2,000 to 6,000 acres in Belize.

RECOMMENDATION:

SESAME

Sesame on-farm trials should be continued because it appears the crop can be grown successfully by small farmers. CARDI believes the growers will be small farmers who have the potential to earn more by producing sesame than by producing corn.

The milpa (slash-and-burn) farmers would fit into this category along with other small farmers who have a very limited number of alternative crops. Sesame is a labor-intensive crop. According to BABCO, sesame required 103 hours of labor per acre and represented 55% of the costs of production. Small farmers would utilize family labor and make minimum cash inputs.

Sesame is a traditional crop in neighboring countries, and there is a domestic demand for sesame seed in Belize. Processing is not required. Unprocessed sesame has recently been sold for as much as BZ$ 1.00 per pound in the domestic market. Potential selling prices are two to three times the indicated value of soybeans grown in Belize, and this makes sesame seed too valuable for livestock feeding.

RECOMMENDATION:

SOYBEANS

The establishment of a private sector soybean processing facility should be encouraged in Belize initially to produce full-fat soybean meal for the import substitution of feed concentrate.

It has been demonstrated that soybeans can be produced at a cost of approximately BZ 26 cents per pound. Experienced, well equipped farmers would be expected to produce soybeans at a lower cost. Large farmers can be expected to accept a lower cash return per acre, and realize a profit on volume.

Soybeans could be sold at this time for BZ 33 to 35 cents per pound.

The initial goal should be to harvest and process 2,000 acres of soybeans in Belize. This acreage should provide the approximate quantity of soybeans required to produce the tonnage of either full-fat or low-fat soybean meal for the import substitution of concentrates as estimated by Mr. Reimer.

The production of 2,000 acres of soybeans should produce the approximate quantity of soybeans to closely match the 700-pound-per-hour capacity of a small extruder. A larger model extruder is available with the capacity of 1,800 pounds per hour.

On-farm trials and increased acreage should be encouraged. The growing and harvesting of 2,000 acres of soybeans would be a major undertaking in Belize. A soybean processor should be granted permission to import soybeans for an infant industry, duty free, for a period of time until local production can be assured. Present duty on soybean imports:

On CIF Value	Caricom Countries	Non-Caricom Countries
Stamp	12%	12%
Duty	0%	12%
Total	12%	22%

The Wall Street Journal (January 11, 1988), (p. 23) shows the recent cash price of soybeans in Central Illinois was BZ 20 cents per pound, and the price a year ago was BZ 16 cents per pound. Soybeans are normally handled in bulk, but would probably have to be bagged for this purpose.

After experience is gained in processing and reformulation, screw-press oil extraction should be added. It would be a major undertaking for management to make all of the potential changes at one time.

ACRONYMS

BABCO: Belize Agribusiness Company, P. O. Box 92, 1 Arthur Street, Orange Walk Town, Belize, Central America

CAC: Commercialization of Alternative Crops Project

CARDI: Caribbean Agricultural Research And Development Institute, P. O. Box 2, Forest Drive, Belmopan, Belize

CARICOM: Community of Caribbean States: Antigua, Barbados, Belize, Dominican Republic, Grenada, Guiana, Jamaica, Montsterrat, Saint Kits, Saint Lucia, Saint Vincent, Trinidad and Tobago

CIF: Total cost of product, including insurance and freight.

GOB: Government of Belize

INTSOY: International Soybean Program, University of Illinois, College of Agriculture, Urbana, Illinois 61801 USA

MENNONITES: Religious group with strong work ethic. First settled in Belize in 1958. Most of the Mennonites families in Belize originated in Canada. However, some migrated first to Mexico and then to Belize, while others migrated directly from Canada to Belize. Canadian citizenship is maintained, and even Mennonite children born in Belize are being granted Canadian citizenship. The most recent census indicates there were approximately 1,000 Mennonite families residing in Belize.

Official exchange rate: BZ$ 1.00 = US$ .50
US$ 1.00 = BZ$ 2.00

Belize dollar is linked to United States dollar.

SUPPORTING DOCUMENTS

Table 2. GROSS DOMESTIC PRODUCT BY INDUSTRIAL ORIGIN 1983-1985
CURRENT PRICES

INDUSTRY/SECTOR	('000 US $) 1983	1984	1985	PERCENTAGE BREAKDOWN 1983	1984	1985
Agriculture	$25,265	$27,831	$24,384	17.0%	17.1%	14.9%
Forestry & logging	$3,053	$3,141	$2,833	2.0%	1.9%	1.7%
Fishing	$4,959	$5,019	$5,284	3.3%	3.1%	3.2%
Mining & quarrying	$380	$380	$380	0.3%	0.2%	0.2%
Subtotal:Primary	$33,656	$36,370	$32,880	22.6%	22.3%	20.1%
Manufacturing	$16,409	$18,000	$17,343	11.0%	11.0%	10.6%
Electricity and water	$384	$4,754	$5,170	0.3%	2.9%	3.2%
Construction	$8,335	$9,384	$9,020	5.6%	5.8%	5.5%
Subtotal:Secondary	$25,128	$32,137	$31,532	16.9%	19.7%	19.3%
Public Administration	$18,607	$18,667	$18,759	12.5%	11.4%	11.5%
Services	$74,068	$80,370	$83,667	49.7%	49.3%	51.2%
Subtotal:Tertiary	$92,675	$99,037	$102,426	62.2%	60.7%	62.6%
Less imputed banking charges	$2,446	$4,503	$3,323	1.6%	2.8%	2.0%
Gross Domestic Product	$149,012	$163,041	$163,515	100.0%	100.0%	100.0%

Source: Central Statistical Office

Table 3. BELIZE : MAJOR DOMESTIC EXPORTS, 1978 - 1986

	1978	1979	1980	1981	1982	1983	1984	1985	1986
Total Value (in US Million $)									
Current prices	$55.3	$60.8	$81.9	$74.8	$59.8	$65.1	$71.2	$64.4	$72.3
PRODUCTS					PERCENTAGES				
Traditional Agricultural exports	72	68	72	71	72	68	66	61	56
Sugar	60	52	58	57	55	52	46	36	43
Molasses	2	3	2	2	2	1	2	1	1
Citrus products	8	7	8	9	12	11	14	19	16
Bananas	2	6	4	3	3	4	4	5	6
Other Agricultural exports (Nontraditional export crops and livestock products)	not available	2	2	2	2	2	not available	1	1
Total agricultural exports	72	70	74	73	74	70	66	62	57
Fish products	3	7	5	9	10	11	8	12	7
Timber	2	3	1	2	2	2	1	1	1
Garments	17	18	18	14	11	13	21	24	22
Miscellaneous	6	2	2	2	2	4	4	1	3
TOTAL	100	100	100	100	100	100	100	100	100

Sources: Central Statistical Office

THE WALL STREET JOURNAL MONDAY, JANUARY 11, 1988

CASH PRICES

Friday January 8, 1988.
(Quotations as of 4 p.m. Eastern time)

	Fri	Thurs	Yr.Ago
GRAINS AND FEEDS			
Barley, top-qt Mpls., bu	1.9-2.1	1.9-2.1	1.88
Bran, wheat middlings, KC ton	88.00	87.00	52.00
Corn, No. 2 yel. Cent-Ill. bu	bp1.79½	1.79½	1.43
Corn Gluten Feed, Midwest, ton	100.-120.	100.-126.	96.00
Cottonseed Meal, Clksdle,Miss. ton	190-192½	190-192½	148.75
Hominy Feed, Cent-Ill. ton	75.00	75.00	50.00
Meat-Bonemeal, 50% pro. Ill. ton	245.-250.	250.00	190.00
Oats, No. 2 milling, Mpls., bu	n199-209	1.99-2.09	1.67½
Sorghum, (Milo) No. 2 Gulf cwt	3.39	3.41-	2.87
Soybean Meal, Decat, fn	196.-199.	201-204	147.50
Soybeans, No. 1 yel Cent.-Ill. bu	bm6.83½	6.01	4.77½
Sunflwr Sd No. 1 Duluth/Supr cwt	8.20	8.10	6.70
Wheat, Spring 14%-pro Mpls. bu	3.23	3.26½	3.05
Wheat, No. 2 sft red, St.Lou. bu	3.27	3.38½	3.01
Wheat, No. 2 hard KC. bu	3.19	3.23	2.66
FOODS			
Beef, 700-900 lbs. Mid-U.S.,lb.fob	.95	.93	.98
Broilers, Dressed "A" NY lb	xz	.4723	.5123
Butter, AA, Chgo., lb.	1.38½	1.38½	1.26½
Cocoa, Ivory Coast, smetric ton	q2,135	2,114	2,067
Coffee, Brazilian, NY lb.	n1.19	1.19	1.38
Eggs, Lge white, Chgo doz.	.47-.53	.50-.56	.62½
Flour, hard winter KC cwt	7.90	8.05	7.70
Hams, 17-20 lbs. Mid-US lb fob	.62	.63	.60
Hogs, Iowa-S.Minn. avg. cwt	43.75	42.75	48.00
Hogs, Omaha avg cwt	43.10	42.75	47.75
Pork Bellies, 12-14 lbs Mid-US lb	.49	.46	.65
Pork Loins, 14-17 lbs. Mid-US lb	1.04	1.02	1.04
Steers, Tex.-Okla. ch avg cwt	66a.25	66.25	59.25
Steers, Feeder, Okl City, av cwt	83.65	83.65	67.90
Sugar, cane, raw, world, lb. fob	.0935	.0918	.0607
FATS AND OILS			
Coconut Oil, crd, N. Orleans lb.	xxn.28	.28	.18
Corn Oil, crd wet mill, Chgo. lb.	n.22-.22½	.22-.22½	.22
Corn Oil, crd drv mill, Chgo. lb.	.20¾	.20¾	.22
Cottonseed Oil, crd Miss Vly lb.	a.21	.21	.18
Grease, choice white, Chgo lb.	n.15¼	z	.13¾
Lard, Chgo lb.	.17	.16	.16
Linseed Oil, raw Mpls lb.	.25	.25	.25
Palm Oil, ref. bl. deod. N.Orl. lb.	.24½	.24½	.16¼
Peanut Oil, crd, Southeast lb.	.35½	.34½	.23
Soybean Oil, crd, Decatur, lb.	.2195	.2168	.1907
Tallow, bleachable, Chgo lb.	.16¾	.16½	.13¼
Tallow, edible, Chgo lb.	.18½	.17½	.16
FIBERS AND TEXTILES			
Burlap, 10 oz. 40-in. NY yd	n.2740	.2740	.2365
Cotton 1 1/16 in str ho-mid Mphs lb	z	.5928	.5450
Print Cloth, palv/cot. 4s-in. NY yd	s.62	.62	.56
Wool, 64s, Staple, Terr. del. lb.	3.00	3.00	1.90
METALS			
Aluminum ingot lb. del. Midwest	q.89-.91	.87-.88	.5656
Copper cathodes lb	p1.38-.461.38½-.46		.65
Copper Scrap, No 2 wire NY lb	k.96	.95	.45
Lead, lb.	p.38	.38	.28½
Mercury 76 lb. flask NY	q345-355	335.-345.	225.00
Steel Scrap 1 hvy mlt Chgo ton	100.-108	100.-108.	79.00
Tin composite lb.	q4.2817	4.2792	4.1556
Zinc High grade lb	p.45	.45	.42¾
MISCELLANEOUS			
Hides, hvy native strs lb fob	.63	.63	.62
Rubber, smoked sheets, NY lb	nz	.54¾	.45¾
PRECIOUS METALS			
Gold, troy oz			
Engelhard indust bullion	485.37	484.97	403.53
Engelhard fabric prods	509.64	509.22	423.71
Handy & Harman base price	483.90	483.50	402.00
London fixing AM 479.50 PM	483.90	483.50	402.00
Krugerrand, whsl	b486.25	482.50	406.00
Maple Leaf, troy oz.	b500.50	498.00	419.00
American Eagle, troy oz.	b500.50	498.00	419.50
Platinum, (Free Mkt.)	506.50	506.00	525.00
Platinum, indust (Engelhard)	501.25	504.25	n.a.
Platinum, fabric prd (Engelhard)	601.25	604.25	n.a.
Palladium, indus (Engelhard)	129.25	128.25	n.a.
Palladium, fabric prd (Engelhard)	144.25	143.75	n.a.
Silver, troy ounce			
Engelhard indust bullion	6.980	6.995	5.465
Engelhard fabric prods	7.447	7.485	5.848
Handy & Harman base price	6.930	6.970	5.445
London Fixing (in pounds)			
Spot (U.S. equiv. $6.8500)	3.7920	3.8490	2.6985
3 months	3.8750	3.9325	2.7470
6 months	3.9610	4.0165	2.8440
1 year	4.1385	4.1950	4.0370
Coins, whsl $1,000 face val	a5,405	5,435	4,035

a-Asked. b-Bid. bp-Country elevator bids to producers. c-Corrected. d-Dealer market. e-Estimated. g-Mean crop. ex-dock, warehouses, Eastern Seaboard, north of Hatteras. f.-f.o.b. warehouse. k-Dealer selling prices in lots of 40,000 pounds or more, f.o.b. buyer's works. n-Nominal. p-Producer price. q-Metals Week. r-Rail bids. s-Thread count 78x54. x-Less than truckloads. z-Not quoted. xx-f.o.b. tank-cars.

20 Jan-88
F/name: SOYCOMB
R/NAME: COMBINE

Table 2.1 1987 SUMMER TRIALS: SOYBEANS COSTS OF PRODUCTION PER ACRE (C$)
Yields Undifferentiated By Variety

LABOUR USE (MANHOURS)	SOY0187	SOY0287	SOY0387	SOY0487	SOY0587	SOY0687	SOY0787	SOY0837	SOY1187	SOY1287	Trials Average
Land prep	0	0	1	0	0	0	0	0	0	0	0
Plant/reseed	0	0	0	0	0	0	0	0	0	0	0
Thin	0	0	0	0	0	0	0	0	0	0	0
Weed	3	26	21	15	33	10	21	3	22	16	20
Fertilize	3	4	0	4	3	4	4	0	0	0	2
Pest Control	0	3	3	1	3	2	5	3	0	1	2
Research Data	0	0	0	0	0	0	0	0	0	0	0
Preharvest labour	6	33	24	20	39	46	31	6	22	17	24
Harvest	22	0	0	10	24	0	0	0	11	27	9
Threshing	45	44	50	40	20	39	49	7	26	24	34
Total Labour	73	77	74	70	83	85	80	13	59	68	67
COSTS ($)											
Preharvest labour	$11.25	$60.92	$43.91	$37.96	$73.13	$96.76	$57.84	$11.87	$41.26	$30.84	$45.49
Land prep/Seed	$135.74	$143.01	$126.97	$149.02	$301.00	$143.94	$134.62	$103.74	$130.38	$141.75	$151.02
Fertilizer	$95.24	$82.67	$53.71	$79.60	$94.37	$90.97	$50.97	$59.28	$63.14	$59.28	$76.97
Pest control	$38.47	$103.39	$72.40	$43.27	$80.39	$55.96	$113.84	$75.92	$70.35	$90.73	$76.32
Other	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Preharvest field costs	$280.70	$390.19	$303.59	$347.85	$549.39	$389.43	$397.27	$250.01	$313.15	$302.60	$345.78
Harvest & Thresh	$276.47	$222.92	$202.77	$285.75	$278.46	$112.17	$133.37	$63.24	$157.32	$212.97	$210.54
Field production costs	$557.17	$613.01	$566.76	$615.40	$837.85	$562.82	$530.66	$311.25	$470.47	$535.57	$560.32
Management & Admin	$7.51	$5.28	$10.69	$10.41	$11.94	$10.25	$13.83	$7.12	$5.55	$7.41	$9.48
PRODUCT COST	$564.68	$619.29	$577.36	$626.01	$852.49	$573.07	$601.49	$320.44	$478.02	$542.98	$569.80
YIELD (LBS)	1901	1454	2119	2082	2968	2049	2165	1434	1509	1491	1896
GROWER RETURNS											
Crop value(per lb): $0.33	$627.33	$414.48	$699.57	$637.06	$979.44	$676.17	$714.45	$473.22	$497.97	$488.73	$625.68
Prod. costs/acre	$564.68	$619.29	$577.36	$626.01	$852.49	$573.07	$601.49	$320.44	$478.02	$542.98	$569.80
Returns/Acre	$62.65	($204.81)	$121.91	$61.45	$126.95	$103.10	$112.96	$152.78	$19.95	($54.25)	$55.88

Best Available Copy

UFV1SOYA
June87

UFV-1 Variety, 1987 June Plantings
CARDI Trials with Production Greater than 1800lbs/acre

Bz $/lb.

	SOY0187	SOY0387	SOY0487	SOY0587	SOY0687	SOY0787	AVERAGE
Preharvest Labor	$0.005	$0.020	$0.012	$0.024	$0.040	$0.026	$0.021
Land Prep/Seeding	$0.069	$0.059	$0.049	$0.099	$0.067	$0.061	$0.067
Fertilizer	$0.048	$0.025	$0.026	$0.031	$0.042	$0.041	$0.036
Pest Control	$0.019	$0.037	$0.014	$0.026	$0.027	$0.052	$0.029
Preharvest Field	$0.141	$0.141	$0.101	$0.180	$0.176	$0.180	$0.153
Harvest/Thresh	$0.141	$0.095	$0.102	$0.095	$0.085	$0.088	$0.101
Field Production	$0.282	$0.236	$0.203	$0.275	$0.261	$0.268	$0.254
Manage/Admin	$0.005	$0.005	$0.005	$0.005	$0.005	$0.005	$0.005
TOTAL PRODUCT COST	$0.287	$0.241	$0.208	$0.280	$0.266	$0.273	$0.259
Labor % of Total Product Cost	46%	47%	31%	58%	40%	48%	45%

f/name: BZETRADE
r/name: FEED

FEEDING STUFFS FOR ANIMALS	UNIT	1979	1980	AVERAGE 1979/80	1985	1986	AVERAGE 1985/86	CHANGE 1985/86 vs 1979/80	% CHANGE
BRANS, SHARPS, GRAIN SIFTINGS	lb	0	40	20	55,200	2,000	28,600	28,580	142900%
SOYBEAN MEAL	lb	93	0	47	0	0	0	(47)	-100%
TANKAGE	lb	1,084	5,200	3,142	0	0	0	(3,142)	-100%
COCOA SHELLS	lb	0	21,000	10,500	0	0	0	(10,500)	-100%
PET FOOD	lb	363,909	361,331	362,620	485,071	786,591	635,831	273,211	75%
POULTRY FEED	lb	8,205,690	9,154.656	8,680,173	10,013,360	11,394,428	10,703,894	2,023,721	23%
CATTLE FEED	lb	206,909	325,435	266,172	1,740,763	301,893	1,021,328	755,156	284%
PIG FEED	lb	107,724	91,800	99,762	212,243	100,334	156,289	56,527	57%
FEED FOR OTHER ANIMALS	lb	179,709	78,161	128,935	0	0	0	(128,935)	-100%
OTHER SWEETENED FORAGE	lb	0	0	0	153,031	151,423	152,227	152,227	n.a.
		9,065,118	10,037,623	9,551,351	12,659,668	12,736,669	12,698,169	3,146,798	33%

f/name: BZETRADE
r/name: FATOILS

FATS & OILS - EDIBLE	UNIT	1979	1980	AVERAGE 1979/80	1985	1986	AVERAGE 1985/86	CHANGE 1985/86 vs 1979/80	% CHANGE
OTHER ANIMAL OILS & FATS	lb	518	593	555	398	0	199	(356)	-64%
SOYBEAN OIL CRUDE & REFINED	lb	220,635	10,365	115,500	17,153	44,018	30,585	(84,915)	-74%
COTTONSEED OIL, REFINED	lb	294,128	219,660	256,894	127,433	23,910	75,671	(181,223)	-71%
OLIVE OIL, CRUDE & REFINED	lb	110,903	326,318	218,610	139,958	144,480	142,219	(76,391)	-35%
PALM KERNAL OIL, REFINED	lb	285	0	143	0	0	0	(143)	-100%
SUNFLOWER OIL	lb	0	0	0	8	4,088	2,048	2,048	n.a.
GROUNDNUT OIL	lb	0	0	0	0	45	23	23	n.a.
COCONUT OIL	lb	0	0	0	53	0	26	26	n.a.
OTHER FIXED VEGETABLE OILS	lb	94,958	261,705	178,331	193,103	320,805	256,954	78,623	44%
ANIMAL & VEG. OILS MODIFIED	lb	1,673	4,688	3,180	0	0	0	(3,180)	-100%
LARD	lb	3,566,500	3,338,316	3,452,408	2,444,531	3,667,589	3,056,060	(396,348)	-11%
MARGARINE	lb	907,747	1,548,118	1,227,933	1,060,629	915,750	988,190	(239,743)	-20%
IMITATION & LARD SUBSTITUTES	lb	113,389	130,925	122,157	403,827	474,404	439,116	316,959	259%
OTHER MARGARINE	lb	29,300	47,817	38,559	8,501	3,509	6,005	(32,554)	-84%
TOTAL BUTTER	lb	234,056	831,744	532,900	468,425	225,470	346,948	(185,953)	-35%
		5,574,090	6,720,248	6,147,169	4,864,016	5,824,067	5,344,041	(803,127)	-13%

f/name: BEETRADE
/name: MEATS

DESCRIPTION OF IMPORTS	UNIT	1979	1980	AVERAGE 1979/80	1985	1986	AVERAGE 1985/86	CHANGE 1985/86 vs 1979/80	% CHANGE
MEAT PRODUCTS									
BEEF	lb	6,445	0	4,223	27,243	9,494	18,369	14,146	335%
SHEEP	lb	23,820	0	11,910	27,731	20,280	24,006	12,096	102%
PORK	lb	16,042	0	8,021	69,837	40,334	55,086	47,065	587%
BACKS, NECKS, WINGS - CHICKEN	lb	0	23,972	11,986	198	0	99	(11,887)	-99%
OTHER POULTRY PARTS	lb	1,192	1,619	1,406	101,385	0	50,693	49,287	3507%
CHICKEN - WHOLE	lb	37,251	8,100	22,676	0	50,849	25,425	2,749	12%
OTHER POULTRY	lb	99,831	100,340	100,086	101,385	73,555	87,470	(12,616)	-13%
POULTRY LIVER	lb	5,093	1,880	5,487	0	0	0	(5,487)	-100%
EDIBLE MEAT OFFALS	lb	0	66,703	33,351	14,378	8,694	11,536	(21,815)	-65%
PORK SALTED IN BRINE	lb	980,538	947,115	963,827	982,746	989,399	986,073	22,246	2%
BACON	lb	51,259	35,009	43,134	11,763	26,229	18,996	(24,138)	-56%
HAM	lb	196,990	163,822	180,406	128,216	87,240	107,728	(72,678)	-40%
OTHER PIG MEAT -DRY/SMOKED	lb	53,586	13,768	33,677	350	0	175	(33,502)	-99%
BEEF SALTED IN BRINE	lb	23,555	28,770	26,163	2,866	28,490	15,678	(10,485)	-40%
OTHER OFFALS	lb	0	1,302	651	3,612	14,095	8,854	8,203	1260%
LUNCHEON MEAT CANNED	lb	0	0	0	0	354,241	177,121	177,121	n.a.
OTHER MEAT-SALTED/SMOKED	lb	6	20	13	0	0	0	(13)	-100%
MEAT EXTRACTS	lb	1,106	0	553	0	26	13	(540)	-98%
CANNED SAUSAGES	lb	371,264	438,102	404,683	456,704	451,160	453,932	49,249	12%
OTHER SAUSAGES	lb	58,500	33,081	45,791	85,783	119,817	102,800	57,010	125%
CORNED BEEF	lb	319,552	391,802	355,677	277,466	212,909	245,188	(110,490)	-31%
HAM - CANNED	lb	233,687	244,772	239,230	446,146	498,363	473,255	234,025	98%
OTHER PREPARED/PRESERVED MEAT	lb	983,873	969,355	976,614	1,434,427	904,074	1,169,251	192,637	20%
TOTAL MEAT IMPORTS	lb	3,469,590	3,469,531	3,469,561	4,174,236	3,889,249	4,031,743	562,182	16%
PER CAPITA MEAT IMPORTS	lb	23	23		25	24			

f /name: BZETRADE
r /name: FEEDACRE

FEEDING STUFFS FOR ANIMALS	UNIT	1986	NO OIL EXTRACTION: SOYBEANS REQUIRED @ 98 % OF YIELD	NO OIL EXTRACTION: SOYBEAN ACREAGE REQUIRED @ 1800#/ ac.
BRANS, SHARPS, GRAIN SIFTINGS	lb	2,000	NA	NA
SOYBEAN MEAL	lb	0	0	0
TANKAGE	lb	0	0	0
COCOA SHELLS	lb	0	0	0
PET FOOD	lb	786,591	NA	NA
POULTRY FEED	lb	11,394,428	11,626,967	6,459
CATTLE FEED	lb	301,893	308,054	171
PIG FEED	lb	100,334	102,382	57
FEED FOR OTHER ANIMALS	lb	0	0	0
OTHER SWEETENED FORAGE	lb	151,423	NA	NA
		12,736,669	12,037,403	6,687

IMPORT SUBSTITUTION MECHANICAL SCREW-PRESS SOYBEAN OIL EXTRACTION 2 % OIL REFINING LOSS	AVERAGE IMPORTS 1979/80 & 1985/86 lbs	SOYBEANS REQUIRED @ 13 % OIL RECOVERY lbs	LO-FAT MEAL @ 85 % RECOVERY lbs	SOYBEAN ACREAGE REQUIRED @ 1800 #/A Acres
FATS & OILS - EDIBLE				
OTHER ANIMAL OILS & FATS	377	2,959	2,515	2
SOYBEAN OIL CRUDE & REFINED	73,043	573,336	487,336	319
COTTONSEED OIL, REFINED	166,283	1,305,204	1,109,423	725
OLIVE OIL, CRUDE & REFINED	180,414	1,416,122	1,203,704	787
PALM KERNAL OIL, REFINED	71	557	474	0
SUNFLOWER OIL	1,024	8,038	6,832	4
GROUNDNUT OIL	11	86	73	0
COCONUT OIL	13	102	87	0
OTHER FIXED VEGETABLE OILS	217,643	1,708,344	1,452,092	949
ANIMAL & VEG. OILS MODIFIED	1,590	12,480	10,608	7
LARD	3,254,234	25,543,438	21,711,922	14,191
MARGARINE	1,108,061	8,697,496	7,392,872	4,832
IMITATION & LARD SUBSTITUTE	280.636	2,202,794	1,872,375	1.224
OTHER MARGARINE	22,282	174,898	148,663	97
TOTAL BUTTER	439,924	3,453,093	2,935,129	1,918
	5,745,606	45,098,948	38,334,106	25,055

f/name: BZETRADE
r/name: OILACRES

Best Available Copy

f/name: BELIZEDF.WK1
f/name: roast

ROAST-A-IRON ELECTRIC + GAS	SB COST LB BZ$	$B COST/TON FF MEAL BZ$	NEG.COST/TON FF MEAL <3> BZ$	TOT.COST/TON FF MEAL BZ$	TOT.COST/LB FF MEAL BZ$	TOT.COST/TON FF MEAL US$
US$/60LB BUSHEL SB						
12.0	$0.40	$816	$22	$838	$0.4191	$419.10
11.7	$0.39	$796	$22	$818	$0.4087	$408.90
11.4	$0.38	$776	$22	$797	$0.3987	$398.70
11.1	$0.37	$755	$22	$777	$0.3885	$388.49
10.8	$0.36	$735	$22	$757	$0.3783	$378.29
10.5	$0.35	$714	$22	$736	$0.3681	$368.08
10.2	$0.34	$694	$22	$716	$0.3579	$357.88
9.9	$0.33	$673	$22	$695	$0.3477	$347.67
9.6	$0.32	$653	$22	$675	$0.3375	$337.47
9.3	$0.31	$633	$22	$655	$0.3273	$327.27
9.0	$0.30	$612	$22	$634	$0.3171	$317.06

<3>THRUPUT 1000#/HR:
LP GAS: Bz $ 14.31=
3.25 gal/hr x 4.54 #/gal
x Bz $0.485/lb x 2 hrs
LABOR: Bz $ 4.00= 2 hrs
MAINTENANCE: Bz $ 2.00=
U.S.$ 0.50/ton doubled
ELECTRICITY: Bz $ 1.57=
1.92 kwh x Bz $0.41/kwh
x 2 hrs

Estimated duty-free, installed cost of roaster and auxiliary equipment in an existing building.....US$ 26,975

	BZ$
Investment	53,950
Supervision time	5,000
Interest @ 12% per annum	6,474
Depreciation - roaster, 2 year life	9,010
Auxiliary equipment, 5 years	7,186
Insurance	1,200
Analytical	1,200
Office	2,400
Total	32,470

When producing 3,528,000 pounds of full-fat meal, overhead cost would be .0092/lb.

f/name: BELIZEBE.WK1
r/name: elect600
EXTRUDER 600 ELECTRIC
SINGLE ENERGY SOURCE

US$/60LB BUSHEL SB	SB COST LB BZ$	SB COST/TON FF MEAL BZ$	MFG.COST/TON FF MEAL <1> BZ$	TOT.COST/TON FF MEAL BZ$	TOT.COST/LB FF MEAL BZ$	TOT.COST/TON FF MEAL US$
12.0	$0.40	$816	$66	$882	$0.4412	$441.16
11.7	$0.39	$796	$66	$862	$0.4310	$430.96
11.4	$0.38	$776	$66	$842	$0.4208	$420.76
11.1	$0.37	$755	$66	$821	$0.4106	$410.55
10.8	$0.36	$735	$66	$801	$0.4003	$400.35
10.5	$0.35	$714	$66	$780	$0.3901	$390.14
10.2	$0.34	$694	$66	$760	$0.3799	$379.94
9.9	$0.33	$673	$66	$739	$0.3697	$369.73
9.6	$0.32	$653	$66	$719	$0.3595	$359.53
9.3	$0.31	$633	$66	$699	$0.3493	$349.33
9.0	$0.30	$612	$66	$678	$0.3391	$339.12

<1>THRUPUT 2000#/HR
50 HP @.41 KWH = $17.18
2 MEN@$2/HR=$4
2.85HRS(21.18)=60.36
+EST.$6/T REPAIR=$66

Estimated duty-free, installed cost of extruder and auxiliary equipment in an existing building.....US$ 39,397

	BZ$
Investment	78,794
Supervision time	5,000
Interest @ 12% per annum	9,455
Depreciation - all equipment, 5 years	15,759
Insurance	1,200
Analytical	1,200
Office	2,400
Total	35,014

When producing 3,528,000 pounds of full fat meal, overhead cost would be .0099/lb.

f/name: BELIZEBE.WK1
r/name: pto600

EXTRUDER 600 PTO SINGLE ENERGY SOURCE	SB COST LB BZ$	SB COST/TON FF MEAL BZ$	MFG.COST/TON FF MEAL <2> BZ$	TOT.COST/TON FF MEAL BZ$	TOT.COST/LB FF MEAL BZ$	TOT.COST/TON FF MEAL US$
US$/60LB BUSHEL SB						
12.0	$0.40	$816	$95	$911	$0.4557	$455.66
11.7	$0.39	$796	$95	$891	$0.4455	$445.46
11.4	$0.38	$776	$95	$871	$0.4353	$435.26
11.1	$0.37	$755	$95	$850	$0.4251	$425.05
10.8	$0.36	$735	$95	$830	$0.4148	$414.85
10.5	$0.35	$714	$95	$809	$0.4046	$404.64
10.2	$0.34	$694	$95	$789	$0.3944	$394.44
9.9	$0.33	$673	$95	$768	$0.3842	$384.23
9.6	$0.32	$653	$95	$748	$0.3740	$374.03
9.3	$0.31	$633	$95	$728	$0.3638	$363.83
9.0	$0.30	$612	$95	$707	$0.3536	$353.62

<2>THRUPUT 7000#/HR
100HP TRAC.RENT@$27/HR
2 MEN @$2/HR=$4
2.85HRS($31)=$88.85
+EST.REPAIR$6/T=$75/T

Estimated duty-free, installed cost of extruder and auxiliary equipment in an existing building.....US$ 39,397

	BZ$
Investment	78,794
Supervision time	5,000
Interest @ 12% per annum	9,455
Depreciation - all equipment, 5 years	15,759
Insurance	1,200
Analytical	1,200
Office	2,400
Total	35,014

When producing 3,528,000 pounds of full fat meal, overhead cost would be .0099/lb.

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 pre-treatment. 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.

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

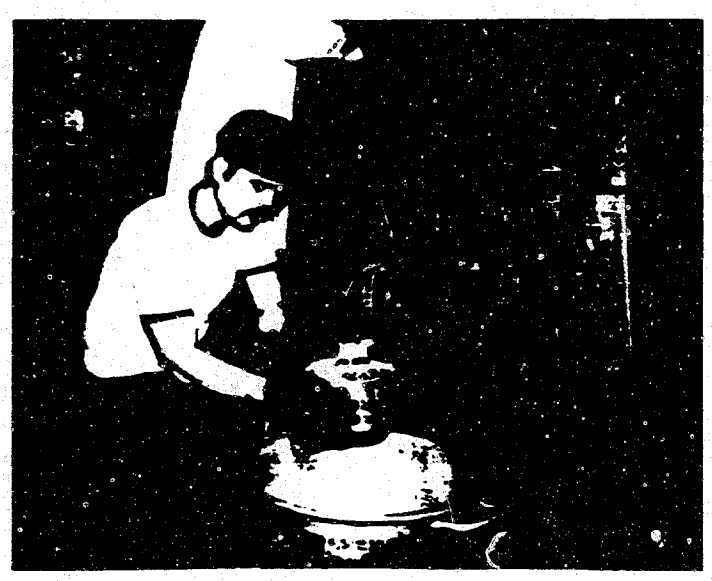

FIG. 1. The INSTA PRO 2000-R extruder.

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 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.

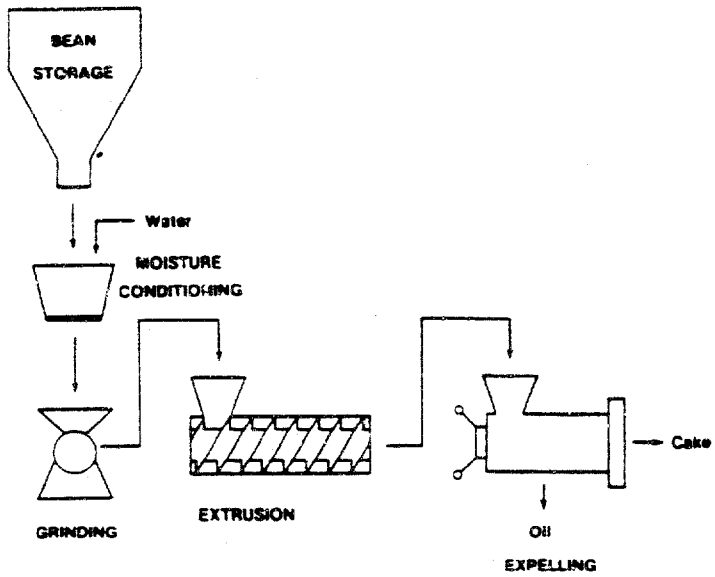

FIG. 2. Flowsheet for the coupled process of extrusion and expelling of soybeans.

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 arbitrary 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

Run	Pressure	Moisture content: Feed to extruder (%)	Moisture content: 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%

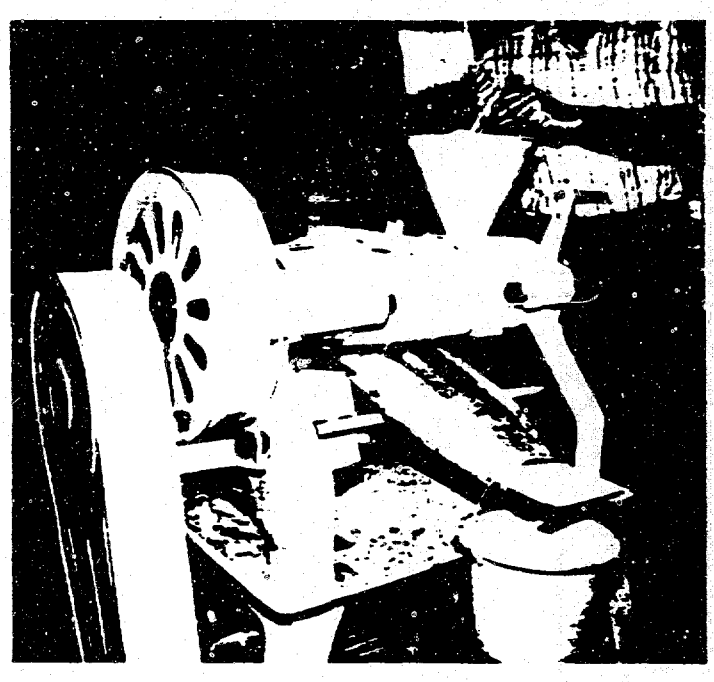

FIG. 3. The Model ZYB-78 Chinese oil expeller.

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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