# A CASE STUDY OF EXPELLER PRODUCTION OF SOYBEAN FLOUR IN INDIA

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# FOREWORD

This report is a case study of soybean processing operations of Agro Processors Private Limited of Nagpur, Maharashtra, India. This small, specialized soybean processing organization needed facilities to produce low-fat soybean flour of high quality with a limited capital investment. The facilities and procedures that are described were evolved by experimentation, largely through a process of trial and error. They illustrate how, by the use of ingenuity, at modest added cost, improvements can be made over conventional techniques used in expeller processing.

The information about capital investments, yields, operating costs, and capacity of facilities is that reported by Agro Processors in 1972. Although it was not verified by detailed investigation, we believe it is dependable. As pointed out elsewhere, it is to be expected that costs and performance will vary under different conditions.

We are deeply indebted to M. S. Parchure, managing director of Agro Processors, who cooperated wholeheartedly in making this information available for publication. It is hoped that his development and sharing of improved technology will set a precedent that will benefit the soybean industry in all countries where it is developing, and thereby the many consumers who can advantageously use soybean flour of high quality.

Credit is due Eldon E. Rice, formerly food formulation technologist, United States Agency for International Development (USAID), New Delhi, for helpful suggestions. The authors are responsible for any errors or other shortcomings in the publication.

## SUMMARY AND CONCLUSIONS

Agro Processors' operations involve production of low-fat soybean flour of high quality by the use of (1) dal-making equipment, (2) a modified expeller, and (3) a pulverizer. Modifications made in the expeller include (1) providing gaps in the conveyor screw, (2) adding a section of "reverse" screw near the outlet end of the expeller box, (3) using high-quality steel for the conveyor screw, expeller box, and cage bars, and (4) reducing the speed of the expeller by approximately one-fourth.

The process involves splitting the soybeans into dal and adding measured quantities of water to the dal and cake before the first and second pressings. Twice-pressed cake, after grinding, may be used for bakery and other products that receive further cooking. To produce flour suitable for consumption with little or no cooking, the material receives a third expelling in which pressure is slightly higher and the interval in the expeller somewhat longer than in the first or second pressing. Operations are performed under sanitary conditions. The procedure recovers a large proportion of the oil. It produces soybean flour of high quality which has received heat treatment suited to its intended use. In acceptance research, respondents' reactions to an 80 to 20 percent blend of whole wheat flour and this flour were relatively favorable. The blend containing this flour received distinctly higher ratings than a blend containing 20 percent full-fat soy flour carefully made by the so-called "village" method.

In 1972 the facilities needed to process 1 ton of soybeans per day involved an investment of about 80,000 rupees. This investment can be reduced if the building is rented rather than owned, if dal is made by hand rather than by machine, or if an existing expeller can be modified instead of getting a new machine.

The operation was budgeted using prices and yields as reported by the company. Soybeans were priced at 1,100 rupees per ton. Product yields and prices were: 60 percent flour at 1,500 rupees per ton, 15 percent oil at 3,000 rupees, 20 percent cattle feed at 300 rupees, and 5 percent waste. With these assumptions, 300 days' operation at capacity with one shift of labor would produce a profit of 36,200 rupees, equivalent to a total return (including interest charged on fixed capital) of 55 percent on the investment in facilities. Capacity operation at two shifts per day would produce higher net returns, while operation at one-half and one-fourth of capacity would result in a modest profit and a small loss, respectively. If the price of soybean flour were 1,250 rupees per ton and other prices the same, operations would be unprofitable even with two shifts at full capacity. However, if soybeans were obtained at 1,000 rupees per ton it would be profitable to produce flour at 1,250 rupees if operations could be maintained at one-half of greater capacity.

The capital investment in solvent extraction facilities of 10 tons per day capacity would be approximately 18 times that for the expeller operation. The high fixed costs for depreciation and interest on investment would permit a solvent extraction plant of that size to compete with the modified expeller only if the solvent plant were operated at or near full capacity. Because of the large investment and high fixed costs, the risk of a heavy loss if operation is considerably below capacity or if there is no remunerative market for the flour is much greater for the solvent than for the modified expeller operation.

These considerations suggest that there may be a place for modified expeller operations under conditions existing in India as well as in other underdeveloped countries where soybean production is limited and soy flour can alleviate nutritional deficiencies. These operations appear best suited to small-volume processors with limited capital and where adapted solvent extraction facilities are unavailable, supplies of soybeans are limited, and neither production nor markets have become stabilized.

# INTRODUCTION

Soybeans are an inexpensive source of high-quality protein. They are especially rich in lysine, an essential amino acid that is deficient in most cereal-based diets.

Soybean flour, which is comparatively easy and inexpensive to process, is one of the most promising forms in which to use soybean protein in the human diet. Acceptance studies of soybean-enriched wheat flour for use in chapatis have shown that most consumers prefer defatted or low-fat soy flour. Those studies also have shown that there will be limited demand for soybean flour for use in chapatis unless it is available at a price that permits consumers to use soy-blended flour with little increase in cost above the cost of wheat flour.[1]

Efficient production of high-quality soybean flour poses problems in areas that are just beginning soybean production. In India most existing solvent extraction plants, which have been designed to process oilseed cake, cannot produce soybean flour of good quality without installing preparation, grinding, and toasting equipment[2]--and some plants are not suitable for such modification. Moreover, in some cases the plants are not located near the major potential areas of soybean production, and shipping rates on soybeans are high.

If operated at or near capacity, large-volume solvent extraction plants with suitable equipment can efficiently process soybeans into oil and high-quality flour. However, such plants involve large investments and high fixed costs, and there is much risk in establishing such facilities before soybean-producing areas are clearly delineated. Moreover, no matter what the location, operating costs per ton for such plants will be excessive if there are not enough soybeans to run them at or near capacity. Unwillingness of potential processors to incur these risks and high costs in the early years of soybean production retards development of a market for soybeans, which, in turn, discourages production.

Because of these conditions, in the early years of soybean production in India there has been considerable interest in using expellers (mechanical presses) to process soybeans. However, the usual practice of double pressing generally leaves approximately 7 percent oil (about one-third of the original oil content of the soybeans) in the cake. This complicates grinding, increases the cost of flour made from the cake, and yields flour of higher fat content than consumers may consider desirable for use in products such as chapatis.

The other disadvantage of conventional expelling grows out of problems in regulating the heat that is generated in processing. Soybeans or soybean products must be heat treated during processing to inactivate antitrypsin and other factors that reduce the nutritional value of the product, to improve flavor, to lengthen shelf life, and to obtain desired functional characteristics in the flour or other end products. Heat treatment should vary with the expected use of the flour. Partial toasting is adequate for flour to be used in baked products such as bread or biscuits, but more complete toasting is needed if the flour is to be used in foods that receive little or no further cooking. Excessive heating must be avoided, however, lest the protein be damaged and the product darkened or scorched. In conventional expelling, it is difficult to provide precisely the amount and degree of heat needed.

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[1] Rathod, K. L., and S. W. Williams. Acceptance of Soybean-Enriched Wheat Flour for Use in Chapatis. Indian Journal of Nutrition and Dietetics, Vol. 10, pp. 18-26. January 1973.

[2] Estimated cost of these modifications was 400,000 rupees (about $53,000) for a plant of 100 tons-per-day capacity. See: Servotech. Soybean Processing Feasibility Study (for USAID, India). Vol. 1, p. 125, 1969.

A small-scale processor cannot exercise the precise control over operations or obtain all the economies of operation that are possible with a large plant. The type of operation described in this study is suggested only for use by processors who, because of a shortage of capital, or limited supplies of raw materials, or aversion to risk, or some combination of these factors, must resort to such equipment and procedures for small-scale operation as are available with limited investment.

## Objectives in Modification of Expeller Operation

The management of the unit examined in this case study was aware of the needs and problems outlined above. It had a limited amount of capital to invest. Its objectives in adapting expeller operations to soybean processing were:

1. Low-cost operation. Production costs had to be reasonable if the products were to sell competitively and in volume.
2. High-quality soybean flour of desired heat treatment. Successful merchandising of edible soy flour requires a product that is low in fat, attractive in appearance, smell, and taste, sanitary, and appropriately heat-treated for its intended use.
3. Maximum recovery of oil. The oil is a valuable constituent of soybeans. Maximum recovery of oil lowers the cost of the cake or flour that is produced in conjunction with it. Apparent consumer preference for soybean flour of low-fat content also makes it desirable to recover most of the oil in processing.
4. High return on capital. The ultimate objective was a profitable operation that would provide a high return on capital. Because soybean protein sells for considerably more as flour than as cake for livestock feed, production of soybean flour was essential if the operation was to be profitable at the price being paid for soybeans.

## Equipment and Modifications

### Equipment Used

The following equipment, installed in a building under sanitary conditions, is used by the firm for the production of expeller-pressed soy flour:

1. Dal-making machine. This electrically operated machine recently introduced by the firm is designed to split the soybeans and to remove the hulls by forced air. It will process approximately 5 tons of soybeans per day (Fig. 2). The dehulled soybean pieces thus produced are locally known as "dal."

   There are two important advantages in using dal in place of whole soybeans in producing soybean flour: (a) It facilitates extraction of the oil. (b) It reduces fiber content of cake, which is desirable in producing soy flour for human consumption.
2. Special soya expeller. With capacity to process 1 ton of soybeans per day, the expeller is specially designed for soybeans. It is electrically powered and is connected to a filter and oil storage unit (Figs. 3-5). (The oil moves by pipe from the expeller to a small covered underground tank in the building, from which it is pumped to an oil filter and stored outside the building.)

**FIGURE 1.** Hand-operated stone mills (above) have traditionally been used to produce dal. They involve little capital investment.

**FIGURE 2.** In hand production of dal, hulls are removed from the cracked soybeans by this ancient method of winnowing.

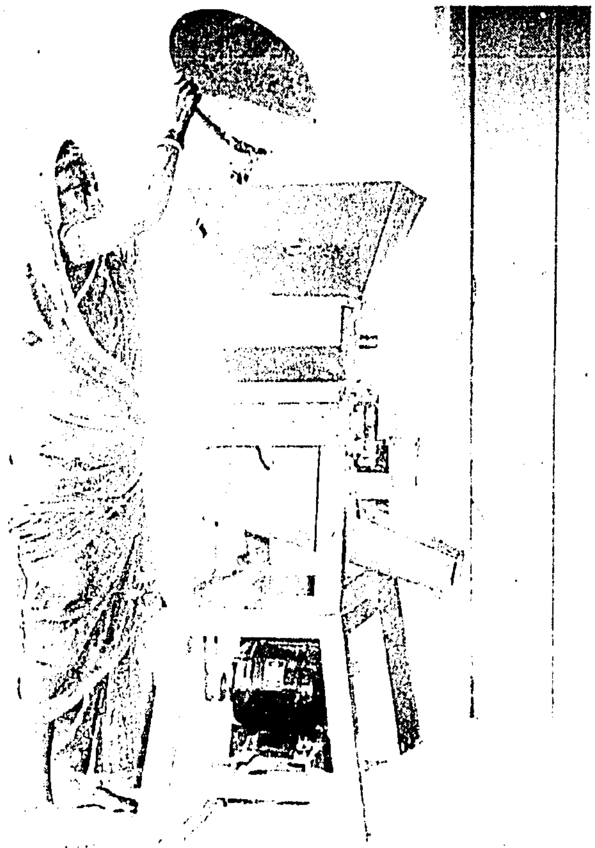


FIGURE 3. A specially designed, electrically operated machine produces dal–dehulled, cracked soybeans–at the rate of 5 tons per day. Hulls are removed by forced air.

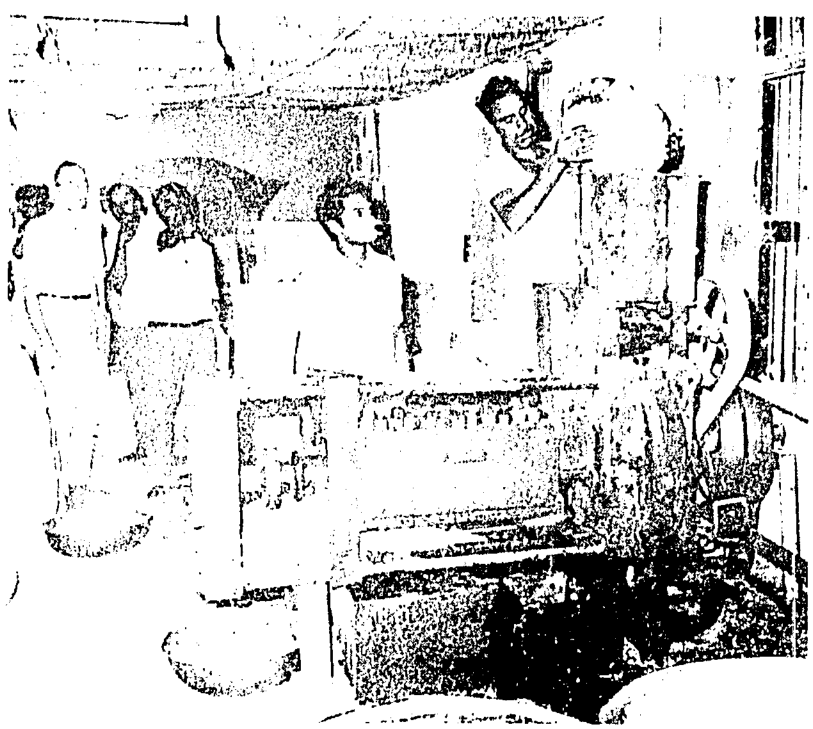


FIGURE 4. Small-scale soybean expeller operation at Agro Processors Private Limited, Nagpur, Maharashtra, India. The equipment is adapted to the production of high-quality soybean flour of low fat content, desirable for use in food products such as chapatis.

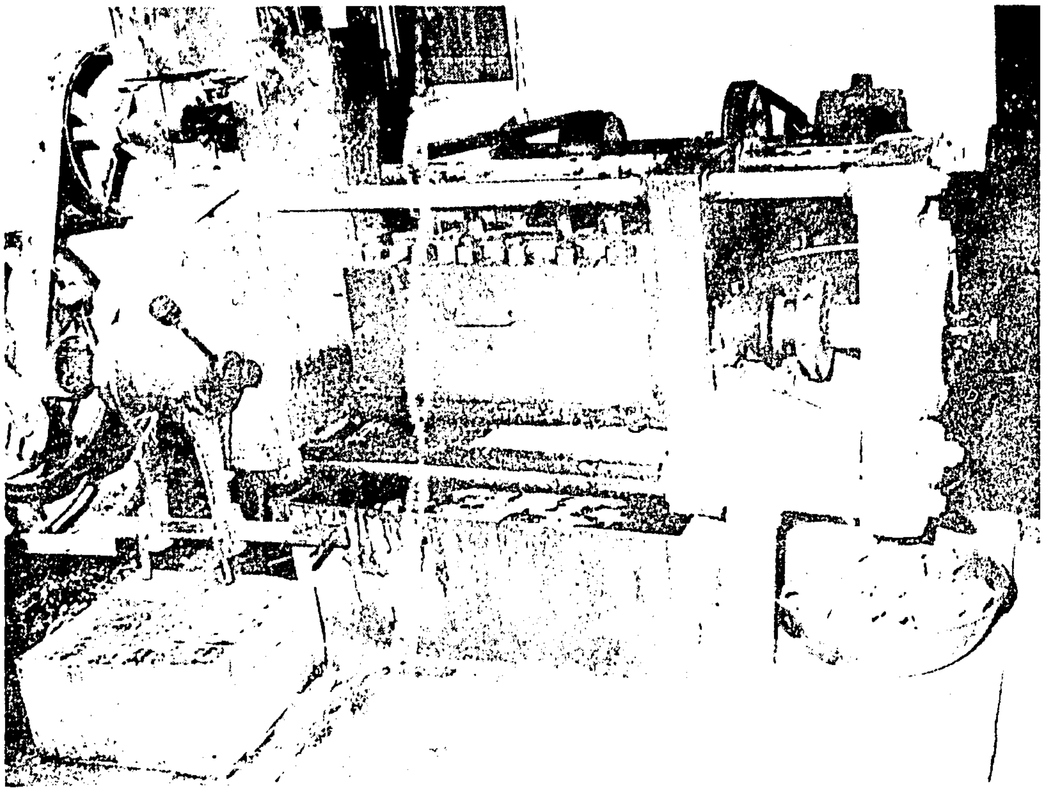
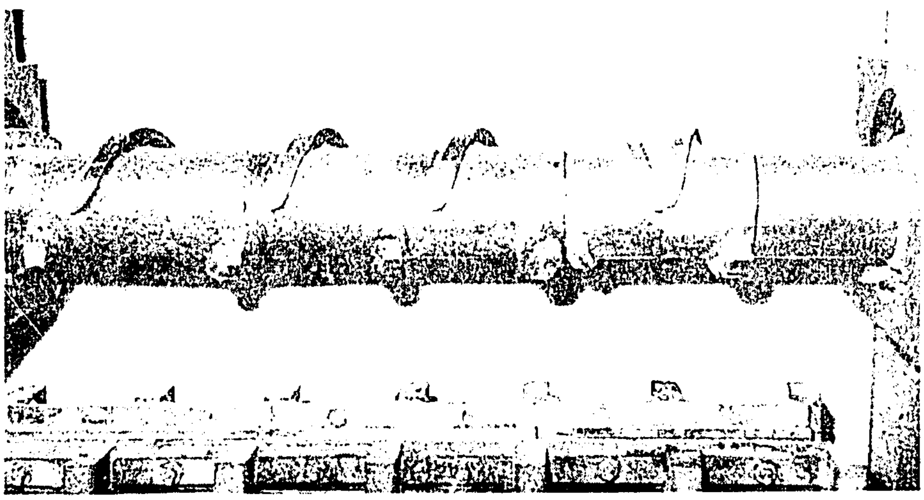


FIGURE 5. Close-up of the expeller (above). As soybeans are crushed within the expeller box, oil passes through cage bars which line the box. The conveyor screw discharges the cake into the basin on the floor. When fully expelled the cake is ground into flour.

FIGURE 6. The steel conveyor screw is designed with gaps and a "reverse" screw, to slow the passage of material through the expeller, thereby maintaining and intensifying the pressure that is exerted upon the material.



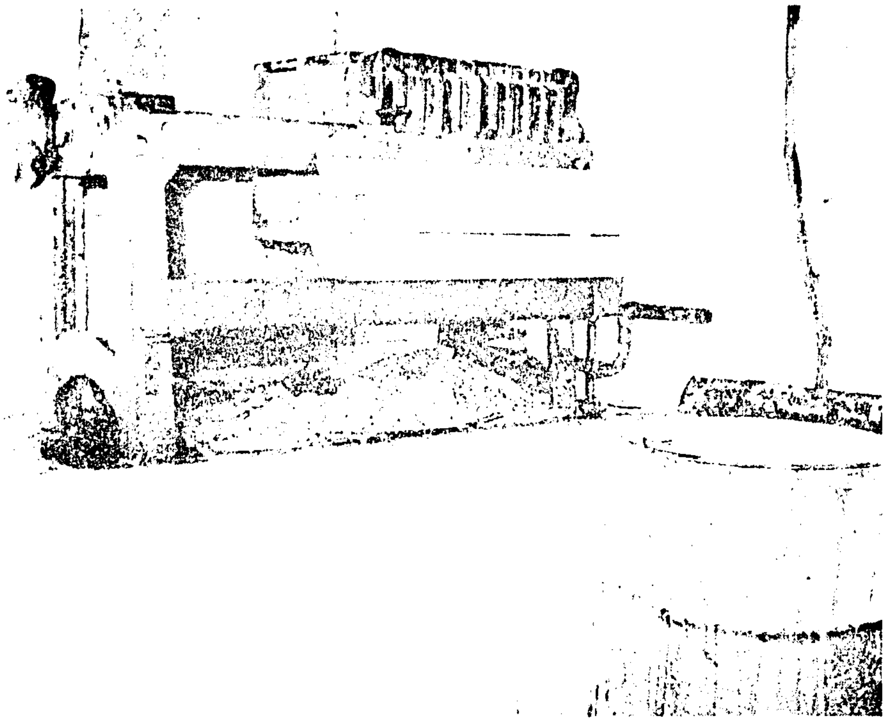


FIGURE 7. At left, soybean oil is filtered and stored outside the building in steel drums.

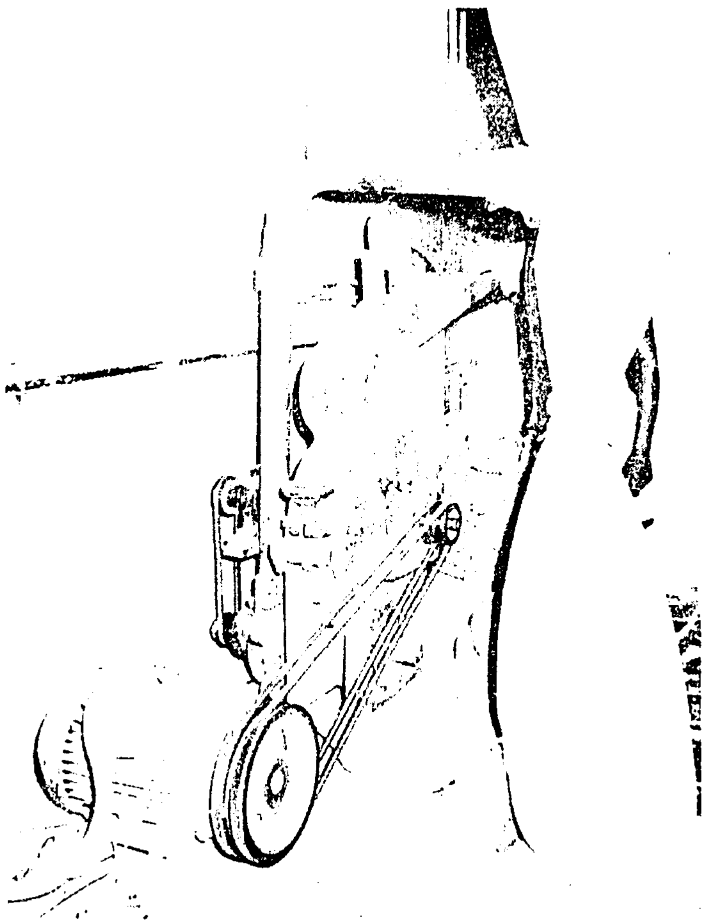


FIGURE 8. The micropulverizer grinds soybean cake into flour of 100-mesh fineness without generating additional heat. This machine produces 8 quintals (0.8 metric ton) of soybean flour in an 8-hour day.

3. Special pulverizer. This micropulverizer grinds soybean cake to flour of 100-mesh size (Fig. 6). The special feature is that no excess heat is generated during grinding. It will produce 8 quintals (0.8 metric ton) of soybean flour per 8-hour day.

4. Other equipment. There is a weighing machine and the firm has a small laboratory with simple equipment for analyzing extent of heat treatment and fat and protein content of soybean cake and flour.

## Modifications in Equipment and Procedure

There are various makes of expellers in India. An expeller consists of a conveyor screw, which is formed by fitting a series of threaded collars, by means of keys, on the shaft of the expeller. The conveyor screw rotates inside the expeller box, forcing the contents through the box under pressure. As the oil is expelled it passes between a series of cage bars lining the expeller box. The expeller box is bolted together by 6 to 12 heavy bolts on each side, depending on length of the shaft.

The small machine used by Agro Processors and its method of operation were modified in these respects:

1. Conveyor screw. Several gaps were made in the conveyor screw to slow the passage of material through the expeller, thereby keeping it under pressure longer (Fig. 6). In addition, a "reverse" screw was added near the discharge end to slow movement of the material and to intensify the pressure. These adjustments eliminate the need for preheating.

2. Expeller box. The expeller box, cage bars, and conveyor screw were made of high-quality steel, to resist wear and tear and to withstand heavy pressure.

3. Speed adjustment. By changing the size of the pulley on the expeller, expeller speed was reduced from the normal 52 revolutions per minute (rpm) to 38 rpm.

4. Added moisture. As described below, measured quantities of water were added to the soybeans and cake before the first and second pressings.

# Making Soybean Flour

## Steps Involved

The steps involved in producing low-fat soy flour are:

1. Cleaning soybeans. Soybeans are hand sorted and cleaned by the use of "sup" (a small winnowing tray) to remove defective soybeans, dirt, and other debris.

2. Making and cleaning dal. Until recently, hand-operated mills (Fig. 1) consisting of two circular stones, of which the upper one is turned by a wooden handle, were used to split the soybeans into dal. In the process, soybeans were dehulled. The dal was separated from the hulls and cleaned by winnowing (Fig. 2). Agro Processors now use an electrically operated 0.5 horsepower dal-making machine (Fig. 3) made to their specifications. The hulls and other materials separated from the dal are sold as cattle feed.

3. Pressing. Pressing in the expeller extracts oil and provides the necessary heat treatment for optimum nutritional value and good flavor in the flour. The cake obtained from the first pressing of the dal is put through the expeller one or two additional times, depending on the use to be made of the flour. The correct proportion of water must be added for efficient crushing. If the water is in excess, the materials are likely to cake on the shaft and block the expeller. If moisture is deficient, expelling is less effective and the material may emerge as powder rather than as cake, with a reduction in the amount of oil expelled. Adding moisture is most effective if done sufficiently in advance of the expelling to allow the moisture to penetrate into the dal or cake.

4. Grinding flour. Cake is ground through a micropulverizer that does not heat the product during grinding. A micropulverizer is used because the oil in expeller cake will gum up a conventional grinding machine of the type used in milling wheat and other grain. Double-pressed cake is put through the micropulverizer twice, yielding soy flour of 100-mesh size.

## Expelling Process

First expelling. For every 10 kilograms of soybean dal (containing approximately 6 percent moisture) 200 grams of water is added. Oil yield is about 5 percent.

Second expelling. Cake from the first pressing is moistened with 100 grams of water per 10 kilograms of cake and rerun for the second expelling. This operation yields about 8 percent oil.

The first and second expelling processes are continuous, with large batches being put through without stopping the machine. When the product containing the flour is to receive further cooking, as in biscuits, bread, chapatis, and the like, expelling is done twice. When the product is intended for direct human consumption, a third expelling (toasting) is necessary.

Third expelling. No moisture is added for the third expelling. A batch of cake from the second pressing is fed to the expeller, and the pressure cone is tightened slightly. When cake from the third pressing has taken on the slightly darkened color that indicates it has received adequate heat treatment, the pressure cone is loosened and the cake released. This procedure results in production by batches and lengthens the time the cake is in the expeller, thereby "toasting" it. It yields flour that may be consumed in products that receive no further cooking.

Temperature inside the expeller during the third pressing has been observed to be near 110° C (230° F). At this temperature, it requires skilled operation of the expeller to determine, by the degree of darkening in color, when the cake has received the desired heat treatment and should be released from the expeller.

## Product Yields

By the process described above, with part of the soybeans being pressed three times and part two times, average product yields per ton of soybeans containing approximately 6 percent moisture were as follows:

0.15 ton oil
0.60 ton flour (5 to 6 percent moisture)
0.20 ton cattle feed (hulls and other material winnowed from dal, plus some material filtered from the oil)
0.05 ton waste (dirt, stones, burned cake, and the like)

It is to be expected that yields will vary depending upon the moisture and oil content and other characteristics of the soybeans and the skill with which they are processed.

Sanitation

Sanitary conditions are needed for production of soybean flour. The building used for this operation had a masonry floor and walls and was screened to keep out birds, rats, and other vermin. Raw materials and products were so handled and stored as to minimize opportunity for contamination.

Analysis of the Flour

Tests of the adequacy of the heat treatment of the flour were made by an independent laboratory. Reported protein dispersibility indexes of flour from the second expelling ranged between 30 and 35. This range indicated that flour from the second expelling was sufficiently heat treated for use in chapatis, biscuits, and other products that would receive additional cooking. Protein dispersibility indexes of flour from the third expelling were below 20, indicating sufficient heat treatment for the flour to be consumed without further cooking.[3]

Acceptance of the Flour

Expeller-processed partial-fat soy flour, produced in the manner described in this publication, was one of three types of soybean flour tested in an acceptance study in Jabalpur, Madhya Pradesh, India. Like the other types of soybean flour used in the study, one part of the expeller-processed soy flour was blended with four parts of whole wheat flour and distributed to households for use in making chapatis.

Respondents' reactions to the blend containing the partial-fat soy flour made in the manner that has been described were relatively favorable. In 20 of the 24 characteristics that were evaluated, respondents' ratings of the blend containing the expeller-processed soy flour did not differ significantly from the ratings of pure wheat flour, which was used as a control. In those same 20 characteristics the blend containing the expeller-processed soy flour received ratings comparable with those given to the blend containing a high-quality commercial grade of defatted soy flour produced in the United States. The four characteristics on which the blend containing the expeller-processed flour were downgraded to a moderate extent were (1) odor given off during cooking, (2) smell of chapatis made from the flour, (3) taste of chapatis made from the flour, and (4) overall palatability of chapatis made from the flour. In all four characteristics, as well as in others, the blend containing the expeller-processed partial-fat soy flour received distinctly higher ratings than the blend containing full-fat soy flour carefully made by the so-called "village" method.[4]

3 Horan, Francis E. Defatted and Full-Fat Soybean Flours by Conventional Processes. Proceedings, International Conference on Soybean Protein Foods, Peoria, Illinois, October 1966. U.S. Department of Agriculture, Agricultural Research Service, 71-35, pp. 129-139, 1967.
4 Rathod and Williams, op. cit.

The adverse reactions to the blend containing full-fat soy flour may have been largely due to its high fat content. If so, the relative preference for the blend containing expeller-processed partial-fat soy flour may have traced in considerable measure to its lower fat content. Whatever the explanation for this preference, an attractively toasted soy flour was produced by using the modified technology in expelling that has been described.

## Economics of the Operation

### Capital Investment

Agro Processors reported the investments in facilities shown in Table 1. The buildings and some of the equipment were built under the firm's direct supervision, with little or no payment for outside professional engineering and supervisory services. A prospective customer who plans to have complete facilities provided to him on a turn-key basis, in which he pays for those services, quite likely will find costs to be higher than those reported here.

Table 1. Investment in Facilities, Agro Processors Private Limited, Nagpur, Maharashtra, India, 1972

| Item | Cost |
|---|---|
| | (rupees) |
| Building (including storage) | 30,000 |
| Special soy expeller, 10 hp, capacity 1 ton soybeans per day, with electrical installation (1 motor) and filter oil storage | 18,000 |
| Dal-making machine, 0.5 hp | 12,000 |
| Special pulverizer, 10 hp, capacity 0.8 ton soy flour (100-mesh) per day | 15,000 |
| Weigh bridge, including transport and installation | 5,000 |
| Total | 80,000[a] |

[a]Approximately $10,670 at the time of the study (7.5 rupees = $1).

An investment of 80,000 rupees is moderate for a soybean-processing and flour-making operation. However, there are alternatives for those interested in operating at reduced capital investment:

1. The largest investment (38 percent of the total) is for building, including storage. Under some conditions it may be possible to avoid this investment by renting a building, which might cost about 300 rupees per month.

2. An investment of 12,000 rupees in the dal-making machine could be avoided by having the dal made by hand-operated mills, each costing 30 to 40 rupees. Eight women with hand-operated mills can process 10 quintals (1 ton) of soybeans into dal per day, at an estimated cost of 5 rupees per quintal.

3. There is also the possibility of modifying existing expeller units for soybean processing. The distinctive feature of the special soy expeller is the shaft, which can be made and fitted in an expeller at an estimated cost of 2,000 rupees. This alternative provides versatility in processing different oil seeds, but it must be weighed in terms of operational feasibility and quality of products to be marketed. Soybean flour for human use should be produced only under highly sanitary conditions. Providing those conditions in an existing plant or rented building may require some capital as well as extra attention to sanitation.

Budget

Table 2 shows the estimated costs and returns for operation at reported capacity (1 metric ton of soybeans per day) for 300 days per year with one shift. This assumes an investment in physical facilities of 80,000 rupees, as shown in Table 1, and price levels reported by the company as shown in the computations. Because prices of vegetable oils fluctuate widely, a conservative price was used in budgeting. During the five-year period 1967-1971, the average wholesale price of groundnut oil was about 4,000 rupees per ton. If prices continue at that level, soybean oil, which sells at a discount, should bring 3,500 rupees or more per ton at Bombay.

If operations could be maintained at the level and prices assumed in these estimates, in less than three years profits would be sufficient to pay back the entire investment in fixed capital. While the estimates used are believed to be conservative, it must be recognized that under some conditions operations might be less profitable than those reported here. Possible effects of operations at partial capacity and at a lower selling price for soy flour are considered in a later section.

If, instead of constructing a building, one were rented for 300 rupees per month (3,600 rupees per year) costs would be somewhat less than the 6,000 rupees per year budgeted for interest and depreciation on the building. Consequently, if the rented building were used for several years, some capital could be invested, if necessary, to adapt it to the flour-making operation without exceeding the building costs included in these estimates. Likewise, if an existing expeller could be satisfactorily modified to process soybeans, operating costs as well as the investment would be somewhat reduced from those shown in the estimate.

If, to avoid investment in a dal-making machine, the dal were produced in hand-operated mills at 50 rupees per ton, costs apparently would increase somewhat over those shown. Estimated cost of making dal with the machine is 12 rupees per ton, computed as follows:

| | Rupees |
|---|---|
| Interest and depreciation (20% per year) | 2,400 |
| Labor to produce 1 ton per day | 900 |
| Electricity and other expense | 300 |
| Annual cost, per 300 tons | 3,600 |
| Cost per ton | 12 |

If operations were at less than capacity, the saving in cost by use of the machine might be somewhat less than this estimate.

Table 2. Operating Costs and Returns at Capacity of One Ton per Day for 300 Days per Year, Agro Processors, Nagpur, Maharashtra, India, 1972[a]

| Item | Cost per Year (rupees) | Cost per Ton Soybeans (rupees) |
|---|---|---|
| Variable costs | | |
| Soybeans, at 1,100 rupees per ton | 330,000 | 1,100.00 |
| Labor | | |
| 3 skilled men at 6 rupees per day | | |
| 3 unskilled men at 4 rupees per day | | |
| 5 women at 3 rupees per day | | |
| 1 supervisor at 10 rupees per day | | |
| 1 clerk/accountant at 10 rupees per day | | |
| Total (65 rupees per day) | 19,500 | 65.00 |
| Electric power, 96 units per day at 0.2 rupee | 5,760 | 19.20 |
| Miscellaneous expenses | 4,740 | 15.80 |
| Interest on three months' working capital, 12% per year[b] | 10,800 | 36.00 |
| Total variable costs | 370,800 | 1,236.00 |
| Overhead costs | | |
| Interest on fixed capital, 10% per year | 8,000 | 26.67 |
| Depreciation on facilities, 10% per year | 8,000 | 26.67 |
| Total overhead costs | 16,000 | 53.34 |
| Total expenses | 386,800 | 1,289.34 |
| Receipts (per ton of soybeans) | | |
| Soy flour, 0.6 ton at 1,500 rupees per ton | 270,000 | 900.00 |
| Soybean oil, 0.15 ton at 3,000 rupees per ton | 135,000 | 450.00 |
| Cattle feed, 0.2 ton at 300 rupees per ton | 18,000 | 60.00 |
| Total receipts | 423,000 | 1,410.00 |
| Net returns | | |
| Profit | 36,200 | 120.66 |
| Return on fixed capital, percent[c] | 55.2 | |
| Per ton of soybeans | | |
| Processing cost | 189.34 | |
| Profit | 120.66 | |
| Break-even point, tons per year | 128 | |

[a]Prices, costs, and yields are as reported by the company; yield takes account of 5 percent waste. As is illustrated in Table 3, if operations are for less than 300 days per year, processing costs per ton will be higher and profits lower than shown here.

[b]Working capital is assumed to turn over within three months.

[c]Includes 10 percent interest on fixed capital in expenses.

## Effects of Changed Conditions

In practice, some conditions may differ from those assumed in the foregoing analysis. For example, operation might be at different levels of capacity than the one shift at full capacity used in the example. Likewise, prices of soybeans or of soybean products might differ from those shown. This section briefly considers the effects of possible differences in these respects upon costs and returns from the operation.

These assumptions were made in budgeting operations at various levels of capacity:

1. That variable costs, and so the amount of working capital, would vary proportionately with the volume of soybeans processed.

2. That depreciation on facilities, like interest on fixed capital, would be constant for any volume that could be processed with those facilities.

Probably neither of these assumptions would prove fully valid in practice. It may be impossible, for example, to reduce variable costs by fully 50 percent if volume is reduced by 50 percent. On the other hand, because of less wear and tear, depreciation on facilities might decrease slightly as processing volume declined. Any errors introduced by these assumptions are at least partially compensating, and are small in relation to computed differences in net returns. Consequently, we believe they do not affect conclusions materially.

This analysis indicates that, at the prices and yields used up to this point in budgeting, operation at one-half of capacity would yield a modest profit (Table 3). At one-fourth capacity, the business would incur a small loss, but, because fixed charges are relatively small, that loss would not be excessive. If the same facilities were used at capacity for two shifts per day, profits would be substantial. These differences reflect relatively high processing costs per ton for operations at one-half and one-fourth of capacity, and a moderate reduction in cost per ton with a two-shift operation.

It is possible that the average price of soybean flour might be below the 1,500 rupees per ton assumed up to this point (this and the other prices quoted are prices at the factory gate). The lower price might reflect either or both competitive pressure on the market or the need to market some of the product, particularly if substandard, for poultry or cattle feed. To illustrate the effect of a lower price, an average price of 1,250 rupees per ton would reduce returns by 45,000 rupees per year (180 tons x 250 rupees per ton) if operation was at capacity with one shift. With this price, the operation would incur a loss of 8,800 rupees per year.

On the other hand, if soybeans could be obtained at 100 rupees instead of 110 rupees per quintal, costs would be reduced by 30,000 rupees per year. With soybeans at that price, flour sold at an average of 1,250 rupees per ton,[5] and all other costs and prices the same as those previously used, the profit from a one-shift capacity operation would be 21,200 rupees per year. Including the 10 percent interest charge, this would be a return equivalent to 36.5 percent on fixed capital. With this combination of prices, operation at one-half of capacity would produce a small profit.

[5] Soybean flour at 1,250 rupees per ton would be priced competitively with besan (bengal gram flour) and with groundnut flour, and would have a large potential market.

Comparison with Solvent Extraction

Because a well-equipped, carefully operated solvent extraction plant designed to process soybeans can produce soybean flour of high quality, a small solvent extraction operation might be considered as an alternative to this modified expeller facility. Rough comparisons will be made of investments and operating budgets with a 10-ton-per-day solvent plant (the smallest for which estimates have been provided by suppliers) designed to process soybeans and operated at various proportions of capacity. In these comparisons, the operating costs used are those estimated by the equipment supplier for a plant producing oil and meal. These may understate the costs of making flour. Yield assumed for the solvent plant is 18 percent oil, 60 percent flour, 17 percent cattle feed, and 5 percent waste. In other respects, the assumptions and basis of computations are the same as those used in preceding sections.

Table 3. Estimated Costs and Returns per Year from Expeller Operations at Various Levels of Capacity with the Same Facilities, Agro Processors, Nagpur, Maharashtra, India, 1972

| Item | One-Shift Operations | | | Two Shifts at Full Capacity |
|---|---|---|---|---|
| | One-fourth Capacity | One-half Capacity | Full Capacity | |
| Operating days | 75 | 150 | 300 | 300 |
| Variable costs, rupees | 92,700 | 185,000 | 370,800 | 741,600 |
| Overhead costs, rupees | 16,000 | 16,000 | 16,000 | 16,000 |
| Total expenses, rupees | 108,700 | 201,400 | 386,800 | 757,600 |
| Receipts, rupees | 105,750 | 211,500 | 423,000 | 846,000 |
| Profit or loss, rupees | -2,950 | +10,100 | +36,200 | +88,400 |
| Return on fixed capital, percent[a] | 6.3 | 22.6 | 55.2 | 120.5 |
| Per ton of soybeans | | | | |
| Processing cost, rupees | 350 | 243 | 189 | 163 |
| Profit or loss, rupees | -39 | +67 | +121 | +147 |

[a]Includes 10 percent interest charged in expenses.

This comparison emphasizes the great difference in investment in facilities, which is 18 times as large for the 10-ton solvent extraction plant as for the modified expeller operation (Table 4). In the solvent extraction plant, the large investment in facilities results in very substantial charges for interest and depreciation on fixed capital. Direct operating expenses per ton are somewhat less and the yield of oil slightly higher for the solvent extraction operation than for the modified expeller. Nevertheless, because of the heavy fixed costs associated with the large capital investment, costs per ton of processing in the solvent extraction plant and the rate of return on fixed capital are comparable with those of the modified expeller operation only when the solvent plant is operated at or near its rated capacity of 10 tons per day. Reflecting the very heavy expense for interest and depreciation on physical facilities, when used at only 10 or 20 percent of capacity the solvent extraction plant would have very high costs per ton and would incur large losses.

Table 4. Summary Comparison of Investments in Physical Facilities, Operating Costs, and Returns from a 10-Ton Solvent Extraction Plant at Various Levels of Capacity and from a Modified Expeller Plant, India, 1972

| Item | 10-Ton Solvent Plant[a] At 10 Tons per Day | At 5 Tons per Day | At 2 Tons per Day | At 1 Ton per Day | Modified Expeller at 1 Ton per Day |
|---|---|---|---|---|---|
| | (rupees) | | | | |
| Investment in physical facilities | 1,450,000 | 1,450,000 | 1,450,000 | 1,450,000 | 80,000 |
| Operating expenses | | | | | |
| Soybeans @ 1,100 rupees, per ton | 3,300,000 | 1,650,000 | 660,000 | 330,000 | 330,000 |
| Direct processing costs[b] | 129,000 | 64,500 | 25,800 | 12,900 | 30,000 |
| Interest on 3 months' working capital (@ 12%) | 102,870 | 51,435 | 20,574 | 10,287 | 10,800 |
| Interest and depreciation on fixed capital (10% for each) | 290,000 | 290,000 | 290,000 | 220,000 | 16,000 |
| Total expenses | 3,821,870 | 2,055,935 | 996,374 | 643,187 | 386,800 |
| Receipts | | | | | |
| Flour | 2,700,000 | 1,350,000 | 540,000 | 270,000 | 270,000 |
| Oil | 1,620,000 | 810,000 | 324,000 | 162,000 | 135,000 |
| Cattle feed | 153,000 | 76,500 | 30,600 | 15,300 | 18,000 |
| Total receipts | 4,473,000 | 2,236,500 | 894,600 | 447,300 | 423,000 |
| Net return | | | | | |
| Profit or loss | +651,130 | +180,565 | -101,774 | -195,887 | +36,200 |
| Return on fixed capital, percent[c] | +54.9 | +22.5 | +3.0 | -3.5 | +55.2 |
| Per ton of soybeans | (rupees) | | | | |
| Processing cost | 174 | 271 | 561 | 1,044 | 189 |
| Profit or loss | +217 | +120 | -170 | -653 | +121 |

[a]The estimate of the investment in the 10-ton solvent extraction plant and of direct processing costs of that plant are from data provided by De Smet (India) Private Limited in 1971. Interest and depreciation charges were computed by the authors on the basis of investments and other costs shown. Estimated costs at 5, 2, and 1 tons per day were computed on the basis of the assumptions stated in the section on "Effects of Changed Conditions." These estimates emphasize the importance of operating the solvent extraction plant at full capacity. [b]At 43 rupees per ton for solvent plant.

[c]Includes 10 percent interest charged in expenses.

For a business expecting to process only one or a few tons of soybeans per day, solvent extraction requires a very large amount of capital. Because of the heavy fixed costs associated with such a large investment, an operation of that type risks heavy losses if the plant is used at only a small percentage of capacity. The modified expeller operation involves much less capital and less risk. If necessary, its capacity can be increased by multiple-shift operations, by use of somewhat larger equipment, or by duplicating equipment that limits output.

Because the price of soybean flour as used in these computations is considerably above the price of soybean meal or cake that is marketed for livestock feed, risk may be higher for a flour-producing operation of the type that has been budgeted than for a conventional processing operation that produces oil and sells meal or cake for feed. If the protein were sold as meal or cake at 600 rupees per ton, instead of flour at 1,500 rupees per ton, receipts would be about two-fifths less than those shown in the budget. Even if operated at maximum capacity, neither the modified expeller operation nor the small solvent extraction operation under consideration could hope to break even under those conditions. However, the amount of loss that would be incurred if the flour-marketing operation were unsuccessful or if the business failed for some other reason would be much less with the modified expeller than with the solvent operation.

An expeller operation also has an advantage in procuring soybeans. In a situation such as that in India, where soybean production is small, and dispersed and transportation is expensive, it is possible to acquire the volume of soybeans needed for a small expeller operation more easily and at lower cost than supplies can be assembled for a solvent extraction plant. Greater assurance of having enough soybeans to operate the plant efficiently, and lower cost of soybeans delivered at the plant, are additional advantages of an expeller operation under these conditions.