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Stabilization of Rice Bran With Extruder Cookers and Recovery of Edible Oil

A Preliminary Analysis of Operational and Financial Feasibility

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Abstract

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This report, which describes technical and economic aspects of edible oil recovery from bran stabilized by extrusion cooking, is based upon 1979 site visits to India, Egypt, and Burma, and interaction with persons involved in those phases of rice delivery systems expected to impinge upon rice bran oil production. Models are described in which bran produced at small or large two-stage rice mills is stabilized either in centralized or decentralized operations and is then subjected to oil extraction and refining. The effects upon return on investment of variable stabilization and bran costs and oil extraction and refining yields are examined. Edible oil recovery from rice bran is shown to be economically feasible under a wide range of technical and economic conditions. Data used to arrive at this conclusion should be applicable to situations in other countries.

This project was carried out by the Office of International Cooperation and Development, and the Western Regional Research Center, U.S. Department of Agriculture, on behalf of the Office of Nutrition, U.S. Agency for International Development.

Keywords: Rice bran, stabilization, extruder cooker, edible oil recovery, cost estimates, sensitivity analysis.

Contents

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Stabilization of Rice Bran with Extruder Cookers and Recovery of Edible Oil: A Preliminary Analysis of Operational and Financial Feasibility

By R. V. Enochian, R. M. Saunders, W. G. Schultz, E. C. Beagle, and P. R. Crowley[1]

Summary

Rice bran, a byproduct of milling paddy rice to remove husk and bran layers when producing white rice, represents a large potential source of untapped edible oil in developing countries. While bran has an oil content of about 15 percent, rapid breakdown of the oil into free fatty acids (FFA) begins immediately after milling. If the prevailing time lag between milling and oil extraction is sufficiently long, high FFA levels (over 20 percent) significantly reduce the value of the oil as a foodstuff. Consequently, most of the oil from the small quantities of rice bran currently extracted is used for soap manufacture. The small amount of rice bran oil suitable for food is obtained only in those few situations where the oil can be extracted within a few hours after milling so as to keep the accumulation of FFA at low levels. Because industrial oils generally cost less than food grade oils, this pattern of utilization results in a lower economic recovery than that obtained from using rice bran oil for food.

Two basic plans are considered for extruder stabilization of rice bran and recovery of edible oil: (1) a centralized stabilizer unit to stabilize bran accumulated from a number of neighboring small rice mills, and (2) stabilizer units installed at individual rice mills. In both cases, oil is recovered from stabilized bran at oil extraction plants.

The analysis indicated that installation of extruder-stabilizing systems in individual small rice mills would probably require capital costs of about $6,200 and would be expected to yield an annual return of 50 percent on the capital investment. Each mill would produce 200 to 300 metric tons (t) of stabilized bran per year or the equivalent of approximately 30 t/year of edible oil. Installation of extruder-stabilizing systems to serve a number of small mills from centralized operations, or at individual large mills, is estimated to require capital costs of about $28,000 and would be expected to yield an annual return on investment of 23 percent in Egypt or 35 percent in India. Either large mills or centralized installations would produce about 4800 t of stabilized bran per year or approximately 600 t/year of edible oil. Systems of these types could lead to the production of as much as 700 000 t of additional edible oil per year in developing countries.

The feasibility of installing and operating extruder cooker systems in developing countries has been demonstrated by the Agency for International Development (AID). The present study concludes that it is operationally and financially feasible to stabilize rice bran and recover edible oil in India, Egypt, and other countries where similar situations exist, using the extruder cooker technology previously demonstrated by AID. This conclusion, however, must be verified by research and development activities to (1) confirm the utility of extruder equipment for rice bran stabilization; (2) demonstrate that extruder-stabilized bran remains stable for a sufficient time to extract oil under practical conditions within developing countries; (3) verify that refined oil from brans of different rice varieties and different environments is of adequate quality for food use and that edible bran oil and defatted rice bran can compete favorably in the markeplace with other oils and compete favorably in the marketplace with other oils and feeds; and (4) verify that local operating conditions, operational factors permit satisfactory financial returns.

If these matters are fully assessed and the findings confirm the operational and financial feasibility of rice bran stabilization and edible oil recovery as predicted in this report, it should be possible to successfully implement this technology on a broad scale.

Rapid bran oil deterioration can be slowed down or stopped by heating the bran immediately after milling to a temperature high enough to destroy the lipase enzyme activity responsible for the deterioration and thereby "stabilize" the bran. Once the bran is stabilized, it can be accumulated and then extracted, using traditional oil extraction methods. Thus, stabilization would make it possible to recover rice bran oil for food use and would increase the economic value of rice bran.

The present study was made to determine the preliminary operational and financial feasibility of rice bran stabilization by extrusion cooking and edible oil recovery in developing countries. The study procedure included literature analysis and visits during 1979 to India and Egypt to examine those components of rice systems that would affect technical and economic aspects of edible rice bran oil recovery in developing countries. The study focuses on rice milling operations, rice bran oil extraction, and the marketing of raw and extracted bran and rice bran oil.

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Introduction

Increased food production is a major focus of development programs in most developing countries. While the primary emphasis of these programs is usually on agricultural development, increased food production can also be derived by reducing postharvest losses and improving utilization of available commodities and byproducts. The U.S. Agency for International Development (AID), in its efforts to assist developing countries, has supported a number of new initiatives to increase food availability through indirect agricultural approaches.[2] One of these initiatives is sponsorship of work with the U.S. Department of Agriculture (USDA) to identify and develop methods for recovering edible oil from rice bran, a major underutilized food resource.

Rice, Rice Bran, and Rice Bran Oil

Rough rice or paddy consists of the white starchy rice kernel surrounded by a tightly adhering brown coating of bran and enclosed within a loose outer hull (husk). During the rice milling process, the hull and bran are removed mechanically to obtain white rice, which is the principal food staple of over 2 billion people. World production of paddy in 1979 was 385 million metric tons (t).

Rice hulls are mainly cellulose, lignin, and minerals and have no significant food or feed value. For the most part, hulls, which average about 20 percent by weight of the paddy, are discarded as a waste material or used as a low-value soil conditioner, fuel, or crude abrasive.

Rice bran, on the other hand, is rich in protein (15 to 18 percent) and food energy and contains high levels of natural vitamins and essential trace minerals. These qualities lead to a high demand for rice bran as an animal feed ingredient, and it is used extensively for this purpose throughout the world. Bran represents from 4 to 9 percent by weight of the paddy, varying with location and degree of milling.

Rice bran contains a good quality oil, which is suitable for use as a salad or cooking oil similar to peanut, cottonseed, or corn oil. The amount of oil in rice bran ranges from less than 10 percent to over 20 percent, depending on the milling process, the amount of contamination of the bran with hull and broken pieces of rice, and whether the bran is obtained from raw or parboiled paddy. Typically, rice bran contains about 15 percent oil when relatively free of hulls, a level approaching that in soybeans, which contain 18 to 20 percent oil. Rice bran has a unique, powerful enzyme system, which is activated during the milling process and causes the rice bran oil to hydrolyze rapidly into free fatty acids (FFA) and glycerine. The rate of hydrolysis varies with temperature and other factors, but can lead to roughly 30 percent of the oil being converted to FFA within a week under tropical storage conditions. Furthermore, when rice bran oil is refined to produce an edible oil, the refining losses recovered for use as soapstock or other industrial uses generally amount to somewhat over twice the amount of the FFA in the oil. Thus, for crude rice bran oil containing 30 percent FFA, less than one-third of the crude oil would be recoverable as edible oil. For this reason, untreated bran must be extracted very quickly after milling, generally within a day, to economically recover edible oil.

Crude rice bran oil with FFA levels of over 10 percent is generally not economically suitable for edible oil production and is designated as industrial grade oil. Industrial rice bran oil is used in the manufacture of soap and for similar items in which FFA can be utilized.

Edible rice bran oil has been recovered on a very limited basis in the United States and certain other locations where rice processing and logistics permit an extremely short interval between milling and extraction of the bran. The time required, however, to collect rice bran, move it from rice mills to oil extractions plants, and carry out the extraction operation is generally too long to undertake practical operations for recovery of edible rice bran oil from untreated bran.

A second major problem related to recovery of edible rice bran oil in developing countries is the practice of milling large quantities of rice in "one-stage" (huller) mills that remove a mixture of hulls and rice bran. When the hulls and bran are so mixed, the oil content is so low (often less than 10 percent) that it is not economically feasible to extract the oil; however, the use of "two-stage" rice mills, in which bran and hulls are recovered separately, is growing.

Although the proportion of rice milled in two-stage mills varies considerably among countries, at least 20 percent of the annual world paddy production is milled in two-stage milling units. Thus, approximately 4.6 million t per year of hull-free rice bran with a high oil content is already available for production of edible oil. If all this available rice bran, which is produced in two-stage mills, were extracted, roughly 700 000 t per year of crude rice bran oil could be added to the world food supply. As the proportion of rice milled in two-stage mills increases, the quantity of bran available for economical oil extraction will increase.

As the rice milling and oil extraction industries are presently constituted, very little of the potential rice bran oil can be recovered in edible form. The speed with which enzymes hydrolyze the oil in the bran and the logistical problems associated with moving the bran to extraction plants and carrying out extraction operations combine to make it nearly impossible to carry out practical recovery operations. Scientists, recognizing the potential value of recovering edible rice bran oil, have sought methods to prevent or slow the hydrolysis of oil in rice bran and thereby provide time needed to transport and extract the bran.

[2] Wilson, D. E., and R. E. Tribelhorn, editors. 1979. Low-cost extrusion cookers. Agency for International Development/U.S. Department of Agriculture-Organization for International Cooperation and Development, Report No. 7 and previous reports in this series.

Rice Bran Stabilization

Scientists have found that the deleterious enzymes in rice bran can be destroyed by heat. When rice bran is held at an elevated temperature for sufficient time, the enzyme action can be slowed or even totally stopped. As in other enzyme inactivation processes, the extent of inactivation increases as temperature, moisture content, and heating time increase. Thus, stabilization of rice bran can be effected over a wide range of conditions. For example, it is known that the enzymes in rice bran containing 30 percent moisture can be destroyed at temperatures of 90° to 100° C when held for 5 to 10 minutes in a steam-injected conveyor screw. In bran containing 10 percent moisture, these enzymes can be destroyed in seconds at 130° to 140°. The literature[3 4] describes a number of processes that can effectively stabilize rice bran. The oil in rice bran stabilized by these methods does not degrade when the bran is stored for several months, and the FFA content essentially remains fixed at the level it was at the time of stabilization. Thus, if bran containing very low levels of FFA is stabilized, it can be stored and extracted later to produce an oil suitable for food uses.

Unfortunately, little published information on these methods is available by which to judge their commercial practicality or financial viability. Clearly, the fact that a given process results in inactivation of enzymes is not in itself sufficient basis to justify the use of that process. The process must be operable on a continuing, relatively trouble-free basis under normal commercial conditions; there must be assured markets for all products and byproducts; and the operation must be financially viable to the extent that the value of the products must cover costs and yield an attractive return. Without satisfying all these requirements, stabilization operations can have no commercial future.

The present study is predicated on the use of extruder cooker equipment for rice bran stabilization for the following reasons: (1) Extruder-cooker equipment is available as standard, mass-produced equipment. (2) Extrusion stabilizers are not dependent on steam as used in other means of stabilization but can be driven by electricity, which is already available in all rice mills in contrast to steam, which is available in very few mills, and, unlike the use of steam, finish drying is not required. (3) Extruder-cooker equipment is simple to install and operate as experienced in other AID-supported projects in developing country settings. (4) Extruder-cooker equipment appears to be adaptable to a wide range of sizes without severe loss in economies. All of these reasons make this technology especially attractive for use in small rice mills of the type found in developing countries.

Rice Bran Oil Processing

Solvent extraction with hexane is the preferred method of recovering oil from rice bran. Before undergoing extraction, rice bran is generally pelletized to improve its handling characteristics. Barber[5] reported that bran stabilized by steam treatment in a conveyor does not need to be pelletized prior to extraction since the stabilization process agglomerates the fine particles. Extrusion cooking of bran would probably also agglomerate the finer particles and obviate the need for pelletizing. This would be of economic value within the context of the present study but needs to be verified. Unlike other vegetable oils, crude rice bran oil contains wax (about 1.5 percent), which should be removed if the oil is to be used as a clear salad oil. This is accomplished by cooling the extracted crude oil and separating the wax by centrifugation.

Thus, refining of crude rice bran oil involves dewaxing, followed by neutralization to remove FFA and some gums, bleaching to remove traces of chlorophyll, and, finally, deodorization. The products of oil processing include refined edible oil, soapstock, wax, and byproducts. Processed rice bran oil is a light-colored, bland, stable oil comparable to peanut, cottonseed, or corn oil. This high-oleic, high-linoleic oil is stable because of its low content of linolenic acid. Smoke, flash, and fire points are comparable to those of other high quality food oils, and its principal food uses would be expected to be for shortening and cooking or salad oils.

Objectives of Study

The objective of this study is to examine the financial and operational feasibility of rice bran stabilization by extrusion cooking for the recovery of edible rice bran oil, and to identify issues that must be addressed in a technology development program for developing countries. The study is based on an analysis of information available in the literature supplemented with a limited amount of supporting information collected from site visits to locations where the technology might be applied. Conclusions about operational and financial feasibility are subject to some uncertainty since they are based on hypothetical field conditions, and, therefore, verification through field testing would be required.

Rice Bran Stabilization Strategies

Rice bran must be freshly milled and relatively free of hulls if it is to be stabilized and used as a source of edible oil. In the ideal decentralized setting, the stabilizing unit would be located in juxtaposition with a rice mill so that within minutes after milling, bran would

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[3]Applied Scientific Research Corporation of Thailand. 1977. Study on the verification and definition of the most suitable rice bran stabilizing technology and specification of its technical parameters. Report to United Nations Industrial Development Organization.

[4]Shultz, E. B., and Morgan, R. P. 1979. Appropriate technology for village-level rice bran processing and utilization in developing countries. Report No. CDT 79/1, Center for Development Technology, Washington University, St. Louis, Mo.

[5]Barber, S. 1979. Instituto de agroquimica y technologia de alimentos, Valencia, Spain. Private communication.

be conveyed to the stabilizer in a continuous operation; this decentralized system is possible at both small and large rice mills. An alternative centralized system would be to install the stabilizer at a central location and ensure the timely collection and delivery of bran from neighboring (satellite) rice mills to the stabilizer. A variation of this centralized system would be to locate the stabilizer at the oil extraction plant. While in the last instance it might be argued that a stabilizer is not required since freshly milled bran delivered to an oil extraction plant could be extracted without being stabilized, in reality a bran inventory and several months storage might be desirable for efficient oil extraction operations.

Rice milling operations and associated commercial aspects are not standardized in developing countries. For example, milling operations differ within areas of a country and between countries. Small two-stage rice mills typically mill 2 t or less of paddy per hour, whereas larger mills sometimes mill up to 8 t of paddy per hour. Oil extraction plant capacities, bran and food oil prices, and labor and energy costs differ among countries.

Because of the diversity of operational techniques and pricing structures, specific country situations must be considered individually to most realistically assess operational and financial feasibilities of different potential systems to be employed in bran stabilization and edible oil recovery. India and Egypt were selected for incountry analysis because they represented diversified milling operations, different price structures, government and private ownership, and different climatic environments. They were also selected because rice bran oil extraction is already practiced (for limited food use in India and for industrial use in both countries) and because both countries have expressed interest in bran stabilization.

India

India,[6] which operates more or less on a free market pricing system with only minimal governmental price structuring, produced about 80 million t of paddy in 1979. About 15 percent of this paddy is milled by two-stage milling, and almost all of this is extracted to recover about 100 000 t of oil. The Indian oil extraction industry generally anticipates a lag time between milling and extraction of up to several months, during which FFA development is severe. The oil typically contains 10 to 50 percent FFA and is predominantly (95 percent) used as an industrial oil. Oil with less than 7 percent FFA is generally used in vanaspati (hydrogenated vegetable oil); this use, which is not more than 5000 t, is small due to the limited availability of low FFA oil.

Edible rice bran oil recovered in India from stabilized bran could approach 100 000 t availability per year and find acceptance as a household cooking oil which, on a refined basis, would compete with cottonseed, sesame, and groundnut oils. At present, India has the capacity of performing all the oil refining steps discussed above except dewaxing, which would be necessary for producing a clear salad oil from rice bran oil.

Because of the widely diverse size and geographical location of two-stage rice mills and oil extraction plants in India, stabilization operations involving both small and large rice mills with location of stabilizers either at the mills or in centralized locations might be possible. Furthermore, since the Indian Government is actively promoting and financing conversion of single-stage mills to two-stage mills, extractable bran resources will increase in future years.

Egypt

Of the annual paddy production in Egypt (about 2.4 million t),[7] 40 percent is milled in the government mills and 60 percent in the private sector. Two-stage milling (which exists only in the government mills) produces 56 000 t of bran that is suitable for oil recovery. Eight rice milling companies within the Ministry of Supply operate 54 mills and mill for 7 or 8 months a year, handling collectively about 5000 t of paddy daily. These mills receive paddy from government stocks. In the present situation, bran from these mills is transferred to oil extraction plants (under the jurisdiction of the Ministry of Industry), which recover oil of high FFA content used in soap manufacture. The defatted bran is transferred at a nominal price to the Ministry of Agriculture for use as an animal feed.

The Ministry of Industry is primarily interested in producing rice bran oil for soap production in their plants and, presumably, would have little interest in producing edible oils for subsequent distribution by the Ministry of Supply, which is responsible for procurement and distribution of edible oils in the country. Under these circumstances, the Ministry of Supply is considering the establishment of an edible rice oil extraction facility within its own organization. The Egyptian concept is to extract freshly milled bran. Because of the coordination and logistic requirements, however, this approach may prove to be impractical. Therefore, Egypt represents a situation where stabilization of bran at each rice mill and recovery of edible oil might be a preferable approach.

Options for Stabilizer Installation

The basic operational options for installing rice bran stabilizers are shown schematically in figures 1A, 1B, and 1C. In 1A, a large centralized stabilizer unit (500 kg bran per hour) is used to stabilize bran that arrives on a daily basis from a number of small satellite rice mills (100 kg bran per hour). Stabilized rice bran is accumulated at the central location to be transported to the oil extraction plant at intervals appropriate to the extraction capacity. The elapsed time between milling and stabilizing would be expected to be about 12 h. FFA development would thus be at a level sufficient to have only a small adverse effect upon refined oil yield.

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[6] See appendix, p.16.

[7] See appendix, p.17.

Figure 1.

Options for installing rice bran stabilizers: M, rice mill; S, stabilizer; E, oil extraction.

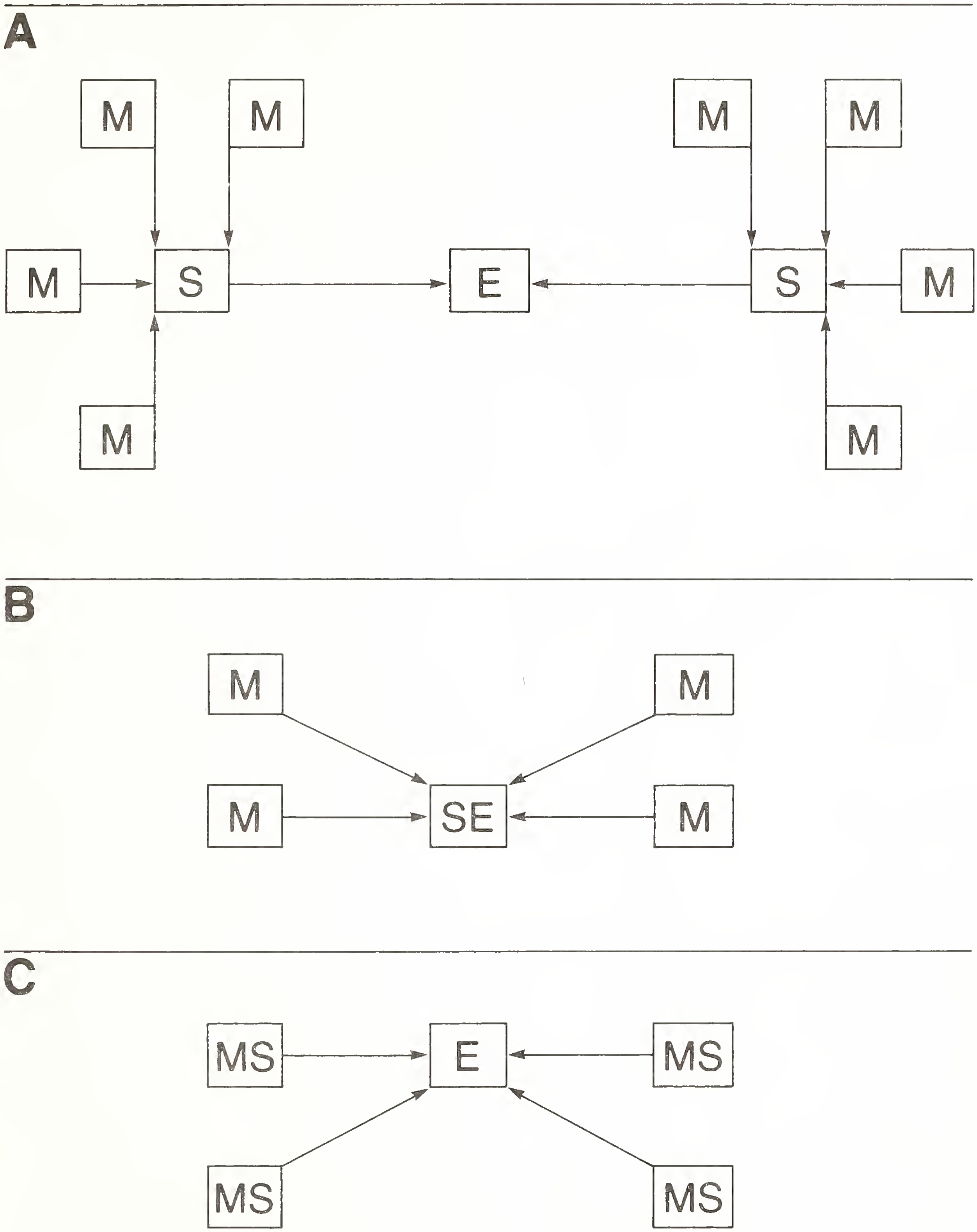


Figure 1B shows a large stabilizer obtaining bran from satellite rice mills and located at the oil extraction plant. Figure 1C shows a decentralized operation in which large stabilizers (500 kg bran per hour) are installed at individual rice mills having a 6- to 8-t paddy-per-hour capacity. Stabilized bran accumulates at each mill, then is transported to the oil extraction plant at intervals dictated by optimum use of transportation, warehousing, and extraction capacities. The plan in figure 1C could also be used to stabilize rice bran directly at small 2-t paddy-per-hour rice mills (100 kg bran per hour). Stabilizers at small mills would provide the advantage of less FFA development as compared with the plan in figure 1A with its correspondingly higher refined oil yield.

Requirements and Costs for Rice Bran Stabilization

Operations that must be performed to recover edible refined oil from stabilized rice bran are given in table 1. In India, stabilization could either be done at each individual mill with small (100 kg bran per hour) or large (500 kg bran per hour) stabilizers, depending on the size of the rice mill, or at central locations with larger stabilizers (500 kg bran per hour), which receive bran from a number of small rice mills. In Egypt, rice bran could be stabilized at individual mills with stabilizers of 500 kg-per-hour capacity. The stabilization operation could be under separate management or integrated with oil extraction and refining under one management. The effect of the principal variables on costs and returns on investment for these strategies in India and Egypt is discussed below.

Table 1.—Operations required to stabilize and transport rice bran to an oil extraction plant and to extract and refine rice bran oil with 2 different systems

Operations when rice bran is to be —	
Stabilized at individual mills	Stabilized at central locations
1. Stabilize and cool rice bran	1. Bag raw bran; place in temporary storage.[1]
2. Bag stabilized bran; place in temporary storage.[1]	2. Sell bagged bran.[1]
3. Sell bagged bran[1]	3. Load and transport bran; unload at central stabilizer.
4. Load and transport stabilized bran; unload at oil extraction plant.	4. Dump bags; stabilize and cool rice bran.
5. Extract oil from bran	5. Bag stabilized bran; place in temporary storage (reuse bags).
6. Bag and sell extracted bran	6. Load and transport stabilized bran; unload at oil extraction plant.
7. Process oil and sell as salad oil.	7. Extract oil from bran.
	8. Bag and sell extracted bran.
	9. Process oil and sell as salad oil.

[1]These operations are performed in rice mills now; therefore, the costs associated with them have been ignored in this analysis.

Equipment and Building Requirements

In this analysis, we assume the stabilizing units, irrespective of capacity, will be the electrically driven extruder-cooker type. With this type of stabilizer, the stabilized bran is expected to be discharged from the extruder at temperatures around 140° C. Therefore, to prevent color deterioration of the rice bran oil, the bran must be cooled before it is bagged and placed in temporary storage. We further assume that evaporative cooling during transfer of the bran on a belt conveyor will be sufficient to prevent excessive color deterioration.

The building for the stabilizing and cooling equipment, the bagging operations, and temporary storage of the stabilized bran should be constructed with concrete floors and reinforced brick walls. In India, adequate space is allowed for storage of about 2 weeks' output of stabilized bran for both the individual and central operations, assuming a 12-h working day in rice mills. In Egypt, space is provided for about 1 week's output, assuming a 24-h workday. Equipment and building descriptions and estimated investment costs are given in table 2.

Table 2.—Equipment and building requirements and costs for rice bran stabilization operations with capacities of 100 kg and 500 kg of rice bran per hour, 1979

Item	Specifications	Investment costs* 100 kg/h	500 kg/h
		Dollars	*Dollars*
Building[1]	Concrete floor and roof with brick walls, reinforced.	[2]3,000	[3]12,000
Stabilizer unit[4]	15-hp motor	[5]2,400	--
	100-hp motor	--	[6]14,055
Conveyor-cooler[7]	3 x 0.3 m, 0.5-hp motor.	750	--
	15 x 0.3 m, 1-hp motor.	--	2,250
Total cost		6,150	28,305

[1]For sheltering the stabilizer and cooling unit and for temporary storage of stabilized bran.
[2]25 m², 3 m high at a cost of $120/m².
[3]100 m², 3 m high at a cost of $120/m².
[4]Includes bran pickup blower conveyor, feed hopper (surge tank), and shipping cost, motors, installation, and contingencies.
[5]Includes $1,000 for stabilizer, $400 for motor, $200 for bran pickup blower and feed hopper plus 50 percent for freight, installation, and contingencies. Based on preliminary estimates by the authors for mass production of small stabilizer units intended only for rice bran stabilization.
[6]Includes $7,800 for the extruder/cooker and motor, $500 for bran pickup blower and feed hopper plus 15 percent ($1,170) for spare parts and 50 percent for freight, installation, and contingencies. Based on 1979 costs of standard extruder available in the commercial market.
[7]Includes installation and contingencies.
*Based on 1979 exchange rate for India of 1 rupee = US$0.128 and for Egypt of 1 pound = US$1.50.

Labor, Bagging, and Transportation Requirements and Costs for Stabilized Rice Bran

With present rice milling operations, rice bran is bagged and sold f.o.b. the rice mill, and bags are recycled and repaired until they are no longer usable. Therefore, when stabilization is imposed on the present system, no additional labor for bagging rice bran at the rice mill nor additional costs for bags are expected to be required.

At each of the small individual rice mills in the Indian model, one additional worker will be required to operate the rice bran stabilizer and keep it in working order. For each of the larger centralized units in India and the decentralized units in Egypt, the additional labor requirement will probably consist of one equipment operator and three workers to receive and dump raw bran, to bag the stabilized bran, and to transfer the bags to temporary storage.

Since bran is currently sold f.o.b. at the rice mill, a cost or charge must be added for transporting bran to the oil extraction plant. Data from India and Egypt indicate that the cost in both countries is $1/t of bran for each 20 km it is transported. Thus, for centralized stabilization plants, the loading and unloading cost per metric ton of bran is $2 because the bran must be loaded and unloaded twice — once when it comes to the stabilization plant from the rice mill and once when it is taken from the stabilization plant to the oil extraction plant.

Annual and Unit Costs of Stabilization

Estimated annual costs for rice bran stabilization, storage, and transportation based on the operational specifications discussed above are given in table 3. Costs for labor, depreciation, insurance, utilities, maintenance of equipment, and interest on debt for working capital are included as production costs. Total annual production costs when divided by the annual output give the costs per metric ton for stabilizing bran. In India, these costs are estimated to be $10.28/t for small decentralized plants and $9.18/t for large centralized plants. In Egypt, the costs are $6.18/t for large decentralized plants. Costs per metric ton for loading and transportation of the rice bran to the oil extraction plant, assuming a distance of 60 km, are also given in table 3. These figures show that with the assumptions used, the costs per metric ton of bran stabilized in the small decentralized plants in India are not a great deal higher (only $0.10/t) than for the larger centralized plant when transportation is included. In addition, because of the shorter time between milling of rice and stabilization of the bran, the FFA content in the smaller decentralized plants is likely to be lower. On the other hand, the centralized plants might be able to achieve more uniform quality control and thus produce a higher quality product more of the time and could be more easily integrated into an oil extraction-refining operation.

Table 3.—Costs for stabilizing, temporary storage, and transportation of rice bran with decentralized and centralized systems in India and Egypt, 1979

	Annual costs*		
	Stabilizer at each rice mill		Centralized stabilizer
	India[1]	Egypt[2]	India[3]
	----------Dollars----------		
Depreciation:[4]			
Equipment	315	1,630	1,630
Building	120	480	480
Insurance[5]	62	283	283
Maintenance, parts, and repairs.[6]	240	2,400	1,200
Electricity[7]	1,200	3,600	6,000
Labor	[8]480	[9]6,120	[9]1,200
Interest cost of working capital.[10]	50	310	217
Total	2,467	14,823	11,010
Costs per ton:			
Production	10.28	6.18	9.18
Load and transport	[11]4.00	[11]4.00	[12]5.00
Total	14.28	10.18	14.18

[1]Stabilization at individual rice mills with 100 kg/h stabilizer. Plant operates for 240 12-h days per year and processes 240 t of rice bran. Assumes 2 h downtime per day (10 h productive time).
[2]Stabilization at individual rice mills with 500 kg/h stabilizer. Plant operates 240 24-h days per year and processes 2400 t of rice bran. Assumes 4 h downtime per 24-h day.
[3]Stabilization is done at central location with 500 kg/h stabilizer. Plant collects rice bran from 5 or 6 small mills, operates for 240 12-h days per year, and processes 1200 t of rice bran per year. Assumes 2 h downtime per 12-h day.
[4]Based on use-life of 10 years for equipment, 25 years for buildings.
[5]1 percent of investment cost per year.
[6]$1/t of bran.
[7]Electricity use is 100 kilowatt-hours (kWh)/t of bran stabilized at $0.05/kWh in India and $0.015/kWh in Egypt.
[8]1 equipment operator to operate and service the stabilizing equipment at $2/day.
[9]Includes 1 worker to operate and service the stabilizer at $2/day ($2.50/8 h in Egypt), 3 laborers to receive and dump raw bran, bag stabilized bran, and sew and move filled bags to temporary storage at $1/day ($2/8-h shift in Egypt).
[10]Assumes cost of interest at 15 percent for 8 months for embodied costs of insurance, maintenance, parts, repairs, electricity, and labor in 1 month's inventory and 1 month's accounts receivable of stabilized bran.
[11]Custom charge per metric ton for loading stabilized bran at rice mill, transporting it 60 km to oil extraction plant, and unloading ($1 for loading and unloading, plus $1 for each 20 km the bran is hauled).
[12]Custom charge per metric ton for loading bran at rice mill, transporting it 20 km to central stabilizing unit, and unloading, plus loading stabilized bran at stabilizing unit, transporting it 40 km to an oil extraction plant, and unloading it ($1 for each loading and unloading, plus $1 for each 20 km the bran is hauled).
*Based on an exchange rate (in 1979) for India of 1 rupee = US$0.128 and for Egypt of 1 pound = US$1.50.

Costs for Oil Extraction and Refining

To estimate extraction and refining costs for this analysis, actual unit costs reported by vegetable oil extraction plants and refineries in India have been used. Bran extraction costs of $29.44/t of bran were reported for plants of about 20 t/day rice bran extraction capacity. Oil refining and other processing costs of $102.40/t of crude rice bran oil were reported, but the capacity of refineries with these costs was not specified. Comparable data for Egypt were not available.

Return on Investment in Rice Bran Stabilization and Oil Recovery

Total costs for producing edible rice bran oil can be estimated as the sum of the costs of stabilizing the rice bran, transporting it to the oil processing plant, extracting and refining the oil, and the cost of the raw material. Raw material costs for producing refined rice bran oil are the cost of the raw bran used, plus an allowance for the moisture and other processing losses (about 5 percent) when the raw bran is stabilized.

The percentage return on investment is a common indicator of the profitability of an enterprise. This return is computed by deducting total annual costs from total annual revenues and dividing the remainder (annual earnings) by the total investment.

The revenue from the production of edible rice bran oil is derived from the sales of the oil, the defatted bran, and byproducts such as soapstock and wax.

The price difference between raw bran and defatted bran varies. In India, a large proportion of the defatted bran produced is exported. This bran sometimes sells for as much as $40/t less than the domestic price of raw bran that, in August 1979, was selling for about $95/t. On the other hand, in the Indian domestic market, defatted bran frequently sells for the same price as raw bran. In Egypt, the price of raw and defatted bran are fixed by the Government and were both about $7.60/t in 1979. The effect of these price variations is analyzed below.

Soapstock[8] and rice bran wax have a higher value than does rice bran. The yield of rice bran wax is not great, and the market for it is not well defined at this time; therefore, its possible recovery and value are ignored in this analysis. The value of soapstock, which is sold for livestock feed and industrial uses, will probably be one-half the value of crude, high FFA rice bran oil.[9] The price for crude high FFA rice bran oil in India in 1979 was about $750/t; therefore, this is the price that has been used for computing costs and returns for producing edible refined rice bran oil in India. In Egypt, the value of crude industrial grade oil or tallow in 1979 was about $300/t.

A number of variables can have a large effect on the return on investment (ROI) in a rice bran stabilization and oil recovery operation. These include the size of the operation, the yields of crude oil from bran and refined oil from crude oil, the difference between the price of raw and defatted bran, the prices obtained from the principal products and byproducts, and the actual investment required, which may vary substantially from an estimate such as the one made in this report.

All of these factors can be accounted for through use of the following equation:

$$ROI = \frac{\text{Annual sales value of all products - Annual costs}}{\text{Total investment}}$$

$$\text{Annual sales value} = (RO_t \times RO_{pt}) + (DB_t \times DB_{pt}) + (SS_t \times SS_{pt})$$

where:

RO_t = Metric tons of refined rice bran oil produced. Computed by $RS_t \times CO_y \times$ decimal equivalent of percent yield refined oil from crude.

RS_t = Metric tons of stabilized bran.

CO_y = Decimal equivalent of percentage yield of crude oil.

RO_{pt} = Price per metric ton of refined oil in dollars.

DB_t = Defatted bran remaining after extraction. Computed by $RS_t\,(1-CO_y)$.

DB_{pt} = Price per metric ton of defatted bran in dollars.

SS_t = Tons of soapstock. Computed by $(RS_t \times CO_y) \times$ (1-decimal equivalent of refined oil yield from crude).

SS_{pt} = Soapstock price in dollars per metric ton.

$$\text{Annual costs} = RS_t\,(RB_{pt} + RS_{ct} + 29.44 + 102.40\,(CO_y) + 0.05D + L_n)$$

where:

RB_{pt} = Price per metric ton of raw bran adjusted for 5-percent loss due to stabilization.

RS_{ct} = Cost per metric ton of stabilizing bran (see table 3).

29.44 = Cost per metric ton of extracting oil from bran.

102.40 = Cost per metric ton of processing crude oil.

D = Distance bran transported in kilometers.

L_n = number of times rice bran loaded and unloaded.

Total investment = investment in rice bran stabilization units and in oil extractor and refinery (from table 2 and text p. 6-8).

We estimated the "most likely" level for each of the variables of this analysis and computed a rate of return based on these most likely levels for four possible types of operations or systems (table 4). These systems are as follows:

System 1.—This system, defined earlier in this report as 1C, small mill application, is for bran stabilization only. It consists of a small stabilizer with a capacity of 100 kg

[8]Soapstock may be either the "foots" from refining an oil or crude oil with too high a FFA content to refine. In this context, it is the foots from refining rice bran oil.

[9]This assumption is based on a communication with the Pacific Vegetable Oil Co., Richmond, Calif. (11-20-79), in which it was related that the price of soapstock from different oils varies, but in the United States it is generally one-half the value of the crude oil from which it is derived.

Table 4.—Annual returns on investment for rice bran stabilization and edible oil recovery under most likely situations in India and Egypt, 1979

Item	Unit	Small stabilizer (India)[1] (system 1)	Extractor-refinery (India)[2] (system 2)	Large stabilizer and extractor-refinery (India)[3] (system 3)	Large stabilizer and extractor-refinery (Egypt)[4] (system 4)
Stabilized bran:					
Production per hour	metric tons	0.1	--	[5]2.0	[6]1.0
Annual production[7]	--do--	240	--	4,800	4,800
Selling price per metric ton	dollars	123	--	--	--
Annual sales value	--do--	29,520	--	--	--
Edible oil:					
Annual production	metric tons	--	576	576	576
Selling price per metric ton	dollars	--	1,152	1,152	720
Annual sales value	--do--	--	663,552	663,552	414,720
Defatted bran:					
Annual production	metric tons	--	4,080	4,080	4,080
Selling price per metric ton	dollars	--	80	80	8
Annual sales value	--do--	--	326,400	326,400	32,640
Soapstock:					
Annual production	metric tons	--	144	144	144
Selling price per metric ton	dollars	--	375	375	150
Annual sales value	--do--	--	54,000	54,000	21,600
Total annual sales value	--do--	29,520	1,043,952	1,043,952	468,960
Annual costs:					
Raw bran[7]	--do--	24,000	--	480,000	38,400
Stabilized bran	--do--	--	590,400	--	--
Stabilization	--do--	2,647	--	44,040	29,646
Extraction and refining	--do--	--	215,040	215,040	215,040
Transportation	--do--	--	19,200	24,000	19,200
Total costs	--do--	26,467	824,640	763,080	302,286
Annual earnings	--do--	3,053	219,312	280,872	166,674
Total investment	--do--	6,150	680,490	793,710	737,100
Annual return on investment	percent	50	32	35	23

[1]Assumes stabilizer unit is located at each rice mill and millers would not be interested in installing unit unless they could make about 50 percent return on their investment; therefore, selling price of stabilized bran set at $123/t to yield this return.

[2]Assumes extractor-refiner, of 20-t rice bran capacity per day, buys stabilized bran from several small rice mills for oil extraction and refining.

[3]Assumes extractor-refiner accumulates raw rice bran from several rice mills for centralized stabilization, followed by extraction and refining of oil.

[4]Assumes rice bran is stabilized at large rice mills and then delivered to extractor-refiner all under one management.

[5]Requires 4 stabilizers, each producing 0.5t/h stabilized bran and operating 2400 h/year.

[6]Requires 2 stabilizers producing 0.5 t stabilized bran each per hour and operating 4800 h/year.

[7]Includes allowance of 5 percent weight loss of raw bran due to moisture and other losses during stabilization.

(0.1 t) of stabilized rice bran per hour, located at an individual rice mill operating for 12 h/day (10 h productive time), 240 days/year. The system is one of several that might be appropriate for India where there are a large number of small, independently owned rice mills. During the visit to India, operators of these mills indicated they would be interested in making an investment in such an operation only if they could be assured of a daily return of 100 rupees (US$12.80), a return on investment of about 50 percent. Therefore, the selling price of stabilized rice bran from such an operation would have to be at a level that would achieve this rate of return. Estimated costs for this system are those developed in a previous section of this report (p. 7).

System 2.—This system is for the oil extraction and refining operation only. It assumes that an oil extractor of 20-t rice bran capacity per day would purchase and accumulate stabilized rice bran from rice mills using system 1, and would then sell extracted oil to other branches of his or her own business or to other dealers at bulk prices.

Costs for this system are based on the quotations of costs received from Indian oil extractors and refiners discussed above. Sales values are based on the assumption that the price of refined rice bran oil would be equal to that of sesame oil, that the price of defatted bran would be 80 percent of the price of raw bran (assumed to be $100/t with 5 percent loss due to stabilization), and that the price of soapstock would be one-half that of high FFA oil in India, which was $750/t in August 1979.

The estimated investment for an oil extraction-refinery operation with a capacity of 20 t rice bran per day was derived from Pe,[10] who estimated that the investment for such a plant in Burma in 1971 would be $340,245. Based on the U.S. Bureau of Labor Statistics wholesale price index for special industry machinery, this investment would probably have doubled for 1979.[11] We assume the plant operates for 24 h/day (20 h productive time), 240 days/year.

System 3.—This system is for a large-scale centralized stabilizer unit in India, defined earlier in this report as 1A. The system is assumed to operate four extruder cookers, each with a capacity of 500 kg (0.5 t) stabilized rice bran per hour operating for 12 h/day (10 h productive time), 240 days/year, integrated with and managed by an oil extraction-refinery with a capacity of 20 t stabilized rice bran per day. Prices of products and investment in the oil extraction-refinery operations are assumed to be the same as for system 2.

System 4.—This system is for large-scale stabilizer units, appended to large rice mills in Egypt, defined earlier in this report as 1C. The system is assumed to operate two extruder cookers for 24 h/day (20 productive hours), 240 days/year, integrated with an oil extractor-refinery as described under systems 2 and 3. Sales prices for products are different in Egypt and India, as indicated in table 4.

Except for system 1, which was computed to return about 50 percent on investment, returns on investment in these systems with the levels of prices and the operating variables assumed, range from about 23 percent in Egypt (system 4) to just over 35 percent in India (system 3). The major reason for this spread is the difference in the price of the refined oil assumed for the two locations.

In evaluating these results, we assumed that a return on investment of 30 percent or more would be very satisfactory because businesses often accept this level of return even with moderate risk. A level of return between 30 and 15 percent may or may not be satisfactory to businesses, depending on the alternatives they have for investments. Finally, a return of less than 15 percent would be considered unsatisfactory because money could normally be loaned out at this rate with little or no risk.

Using these criteria, rice bran stabilization and recovery of edible oil in India appear to be financially sound, whereas they are of questionable soundness in Egypt. However, since prices of bran and oil are fixed by the Government in Egypt without total consideration of financial soundness, the projected return of 23 percent might be sufficient incentive, particularly in light of current interest in reducing foreign exchange requirements for the country.

Effect of Variation in Key Variables on Return on Investment (Sensitivity Analysis)

Although the returns on investment given in table 4 are based on what we believe would be the most probable conditions in India and Egypt, possible ranges in the key variables could have a sizable impact on returns on investment. These effects can be studied by varying one of the variables at a time while holding all others constant for the various systems under consideration.

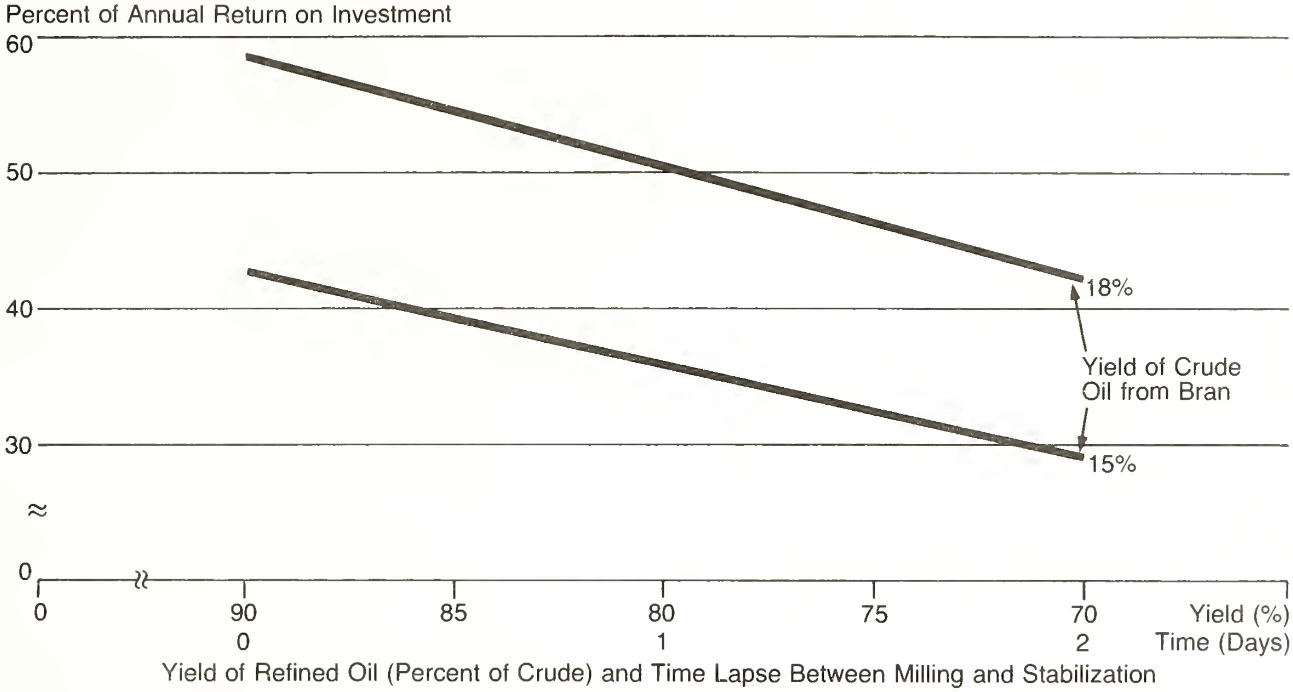
One of the important variables is the time lapse between the milling of rice and the stabilizing of the bran. This time has a significant effect on return on investment because of the increase in FFA with lapsed time and the corresponding reduction in yield of edible oil. Considering system 3 and assuming that rice bran contains 5 percent FFA (equal to 10 percent soapstock) immediately after milling, and that FFA increases about 5 percent/day, the effect of time lapse before stabilization is shown in figure 2 for rice bran yielding 15 and 18 percent crude oil. For rice bran yielding 15 percent crude oil and with a lapse of one day (the most likely situation for centralized stabilization—system 3), the yield of edible refined oil from crude is 80 percent for a return on investment of just over 35 percent. With instant stabilization following milling, the yield of refined oil would be about 90 percent for a return on investment of about 40 percent. With a lapse of 2 days between milling and oil extraction, the yield of refined oil drops to 70 percent for a return on investment of about 30 percent. Thus, for 15 percent crude oil yield and higher, stabilization would be expected to yield a satisfactory return if carried out within 2 days, but would be of questionable profitability with longer time lapses.

At crude oil yields of lower than 15 percent, resulting primarily from a greater content of hulls in the bran, a point would eventually be reached where even immediate stabilization of bran following milling would be of questionable economic feasibility. This effect is illustrated in figure 3, which shows the sensitivity of return on investment to crude oil yields, assuming 90 percent edible oil recovery from crude, which is what would be expected with immediate postmilling stabilization. The return on investment shown in figure 3

[10] Pe, M. 1971. Rice bran oil technology. United Nations Industrial Development Organization Bulletin 1D/Wg. 89/6.
[11] The index for special industry machinery (Code 11-6) was 120.9 in 1971 and averaged 242.0 for the first 7 months of 1979.

Figure 2.

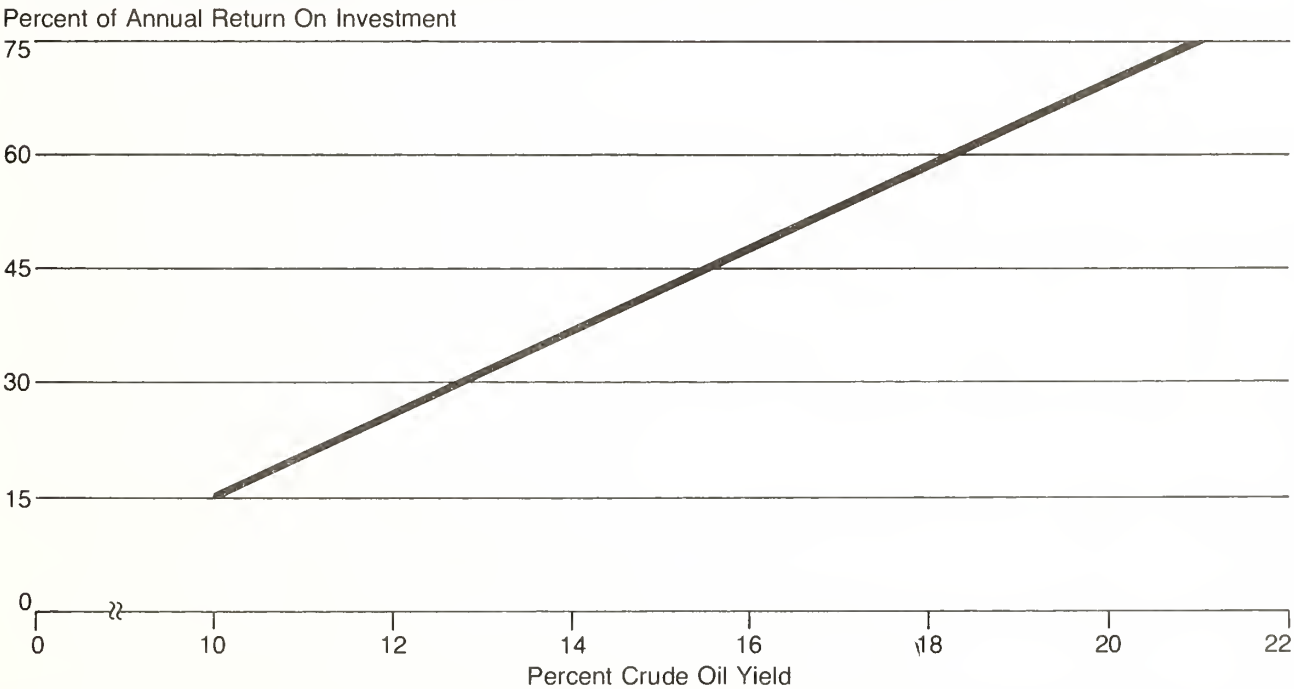
Effect of time between milling and stabilization of rice bran and oil yield on annual return on investment, India 1979.



Assumptions: Oil extractor-refiner collects bran from several rice mills, stabilizes at centralized location, and transports it to extraction point. Raw bran sells for $100/t, defatted bran for $80/t.

Figure 3.

Effect of crude oil yield from stabilized bran on return on investment, India, 1979.



Assumptions: Centralized stabilization (system 3). Yield of refined oil from crude is 90-percent; raw bran sells for $100/t, defatted bran for $80/t; price of refined rice bran oil is equal to sesame oil ($1,152/t) ranges from 15.5 percent for 10 percent crude oil yield to about 75 percent for 21 percent crude oil yield.

Figure 4 shows the effect of the price received for refined rice bran oil on return on investment. If the price were equivalent to that for sesame oil, $1,152/t (assumed most likely for India—system 3), the return would be just over 35 percent. This would range from about 20 percent, if the oil sold for $949/t (the price for rape and neem oil), to over 41 percent if the selling price were $1,235/t (the price for groundnut oil). At a price for refined oil of about $900/t, the return on investment would be too low to be satisfactory. At a price of $1,100/t for edible oil, the return on investment would be over 30 percent and, therefore, satisfactory. At prices for oil between these ranges, the acceptability of the return on investment would depend on what other options an investor might have. Thus, if rice bran oil can be priced at roughly 93 percent or more of the price of sesame oil, or roughly 87 percent or more of the price of groundnut oil, rice bran stabilization would be expected to be financially sound.

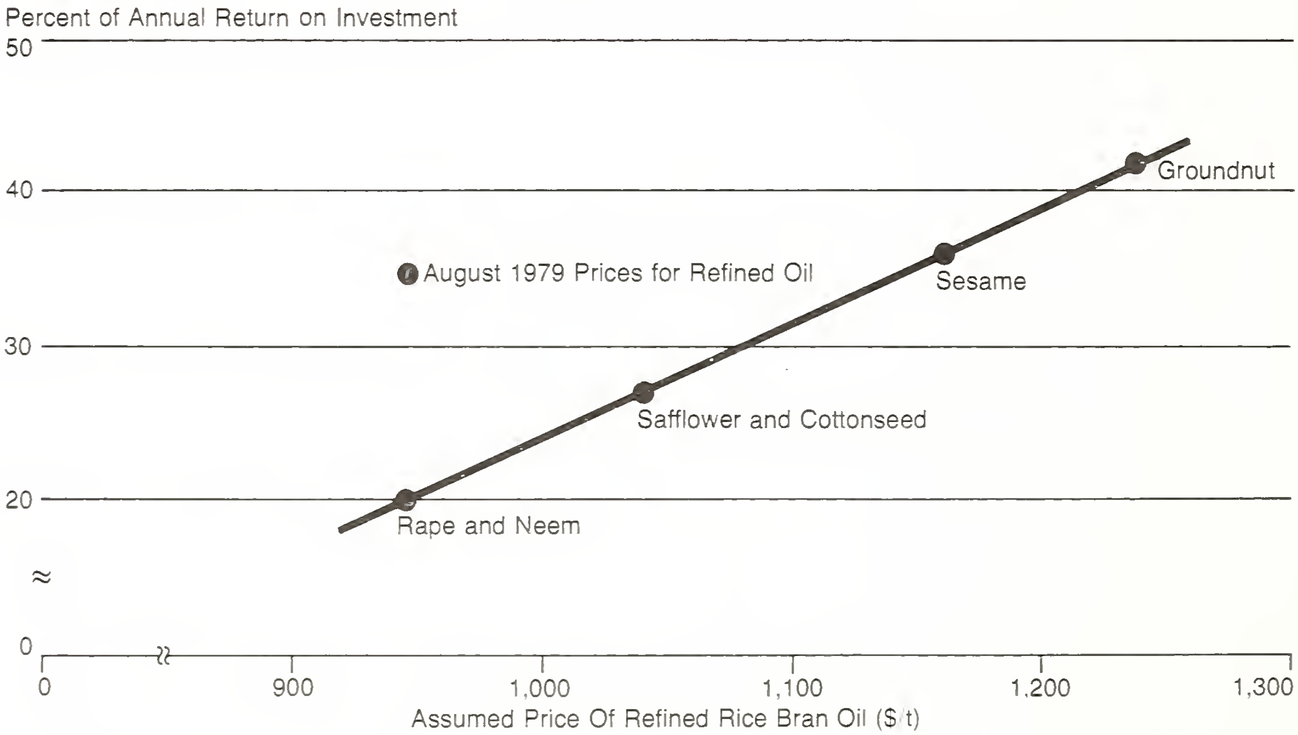
The effect of the comparative value of defatted and raw bran is shown in figure 5. This figure shows that if the price of defatted bran were 80 percent of raw, with the price of raw bran being $100/t (the most likely situation for India—system 3), the return on investment would again be just over 35 percent. The return on investment would be unsatisfactory only when the ratio of the price of defatted to raw bran dropped to 0.5 while the price of rice bran oil was equivalent to that for sesame oil. At a ratio of 0.7 and higher, the return on investment would be very satisfactory.

Figure 6 shows the effect of different rates for electricity on return on investment. For system 1 (stabilizer only), when the cost used for electricity is $0.05/kWh, the return is 50 percent on investment when the price of stabilized bran is $123/t. At this price for stabilized bran, changes in the rate for electricity have a significant impact on return on investment. As shown in figure 6, the return on investment for system 1 ranges from 60 percent, when the rate for electricity is $0.025/kWh to 10 percent when the rate is $0.15/kWh. For system 3 (India) and system 4 (Egypt), the effect shown is not as dramatic because the different rates for electricity are applied only to the electricity used for operating the stabilizer and not for the oil extraction and refining operations. Therefore, where the rate for electricity is high, stabilization by a heat source other than electricity should be seriously considered.

Finally, figure 7 shows the effect of the investment cost of the stabilization unit on return on investment. For the small stabilization unit by itself (system 1), if there is a 50 percent change in either direction from the "most likely" investment cost, the rate of return on investment would range from a high of 115 percent to a low of 28 percent, indicating that a sizable increase in investment

Figure 4.

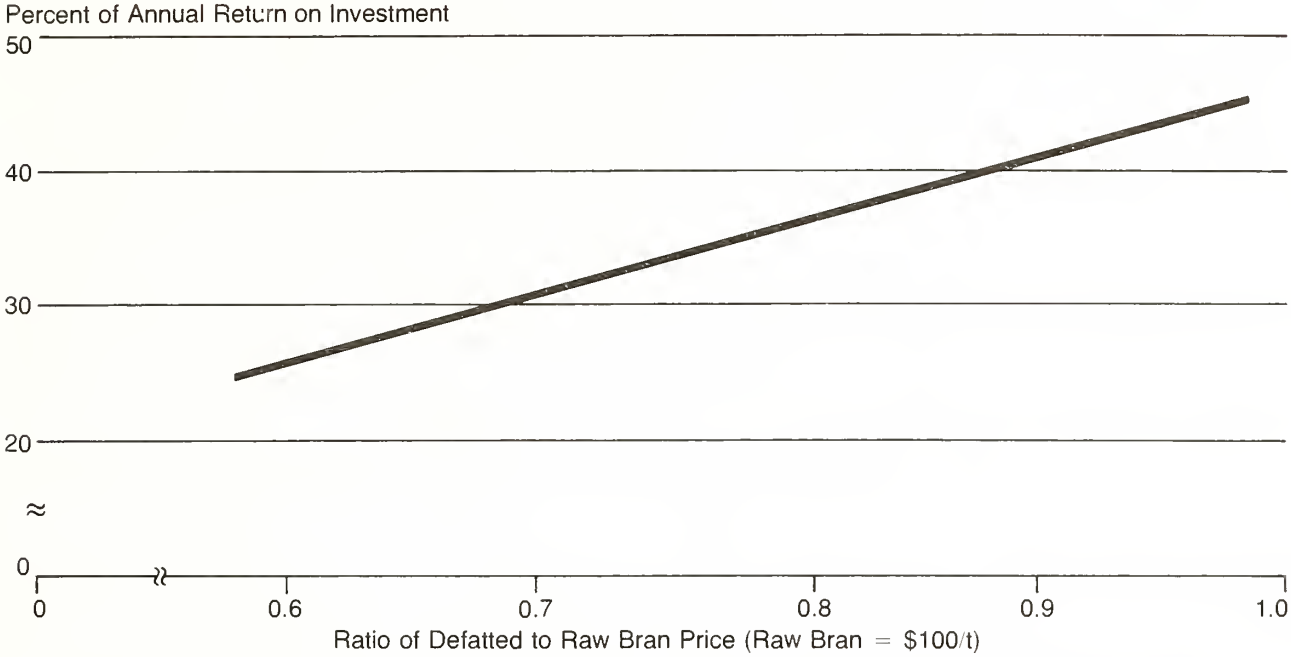
Effect of price received for refined rice bran oil on return on investment, India 1979.



Assumptions: Large scale centralized stabilization of bran; raw bran sells for $100/t, defatted bran for $80/t; 15-percent crude oil yield; 80-percent refined oil yield from crude.

Figure 5.

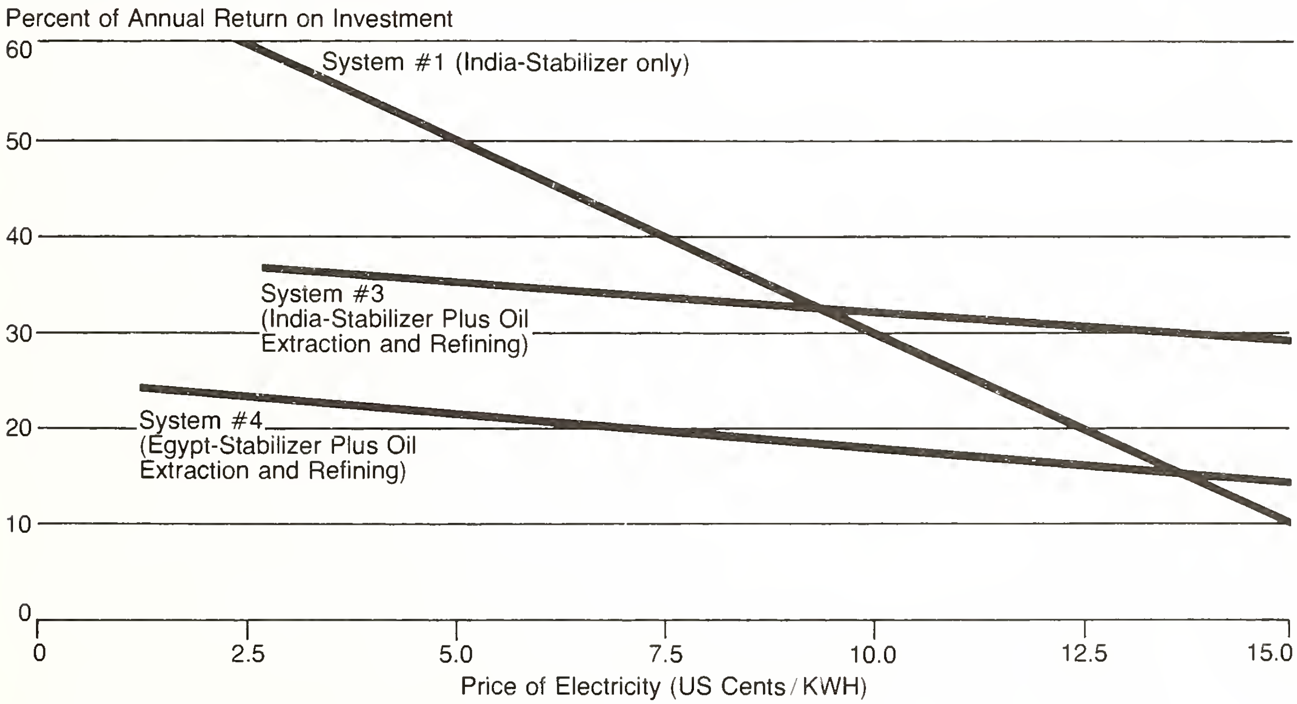
Effect of the comparative value of raw and defatted bran on return on investment, India 1979.



Assumptions: Large scale centralized stabilization of bran; raw bran sells for $100/t, defatted bran for $80/t; 15-percent crude oil yield; 80-percent refined oil yield from crude.

Figure 6.

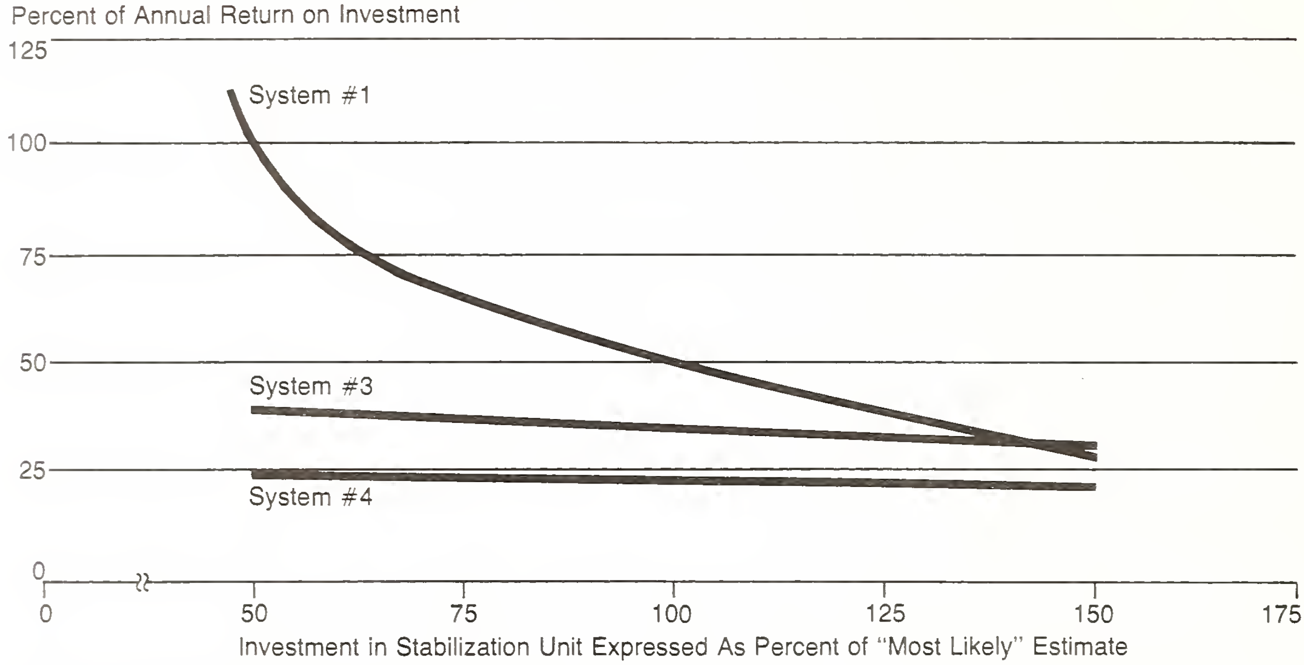
Effect of the cost of electricity on return on investment, 1979.



Assumptions: See table 4 for description of systems.
Systems assume change in price of electricity for operation of stabilizer only.

Figure 7.

Effect of cost of stabilization unit on return on investment in rice bran stabilization followed by oil extraction and refining, India 1979.



Assumptions: Large scale centralized stabilization of bran; raw bran sells for $100/t, defatted bran for $80/t; 15-percent crude oil yield; 80-percent refined oil yield from crude.

(nearly two times) can be made and still yield a reasonable return. For this range in the investment cost of the stabilizer unit for systems 3 and 4, the effect on return on investment is much less sensitive because the investment in the stabilizer is only a small part of the total investment in stabilization and oil extraction-refining combined. Within the range of investment costs considered, the return on investment for system 3 in India seems to be satisfactory, whereas for system 4 in Egypt it is in the questionable range.

Conclusions and Recommendations

On the basis of the foregoing analysis, it appears, under selective conditions, to be operationally and financially feasible to stabilize rice bran by use of extrusion cooking for the production of edible rice bran oil. Installation of stabilizers in small two-stage rice mills in India would be expected to require fixed capital costs of approximately $6200, and yield 50 percent on investment. Each mill could produce about 200 to 300 t/year of stabilized rice bran, or indirectly, 30 t of edible oil. Installation of extruder cookers at larger two-stage rice mills or in a centralized location serving a number of small mills would require fixed capital costs of approximately $28,000 investment each and would yield a return on capital investment of 23 percent in Egypt and 35 percent in India. Depending on annual hours of operation, stabilizers at large mills or at centralized locations would produce 1200 to 2400 t/year of stabilized bran, equivalent to 150 to 300 t of edible oil. While these data have been derived from conditions prevailing in India and Egypt during August 1979, the foregoing method of analysis can also be applied to other countries where two-stage rice milling is employed. A return on investment for other country situations can then be examined by potential investors in light of the local economic conditions.

A principal element of uncertainty related to stabilization at individual small rice mills is the lack of a commercially available 100 kg/h extruder cooker. While it appears likely that an extruder cooker of appropriate size and cost to permit adequate returns to the miller can be developed, design and development of new equipment are not recommended at this time. We recommend that the technical and economic feasibility of extruder cooker stabilization be first verified through adequate field testing of commercially available larger extruders. If these tests are conclusively positive, smaller extruder cookers can be designed to permit stabilization in individual small rice mills.

Several elements within this analysis need verification. Primarily, optimum operating conditions for the extruder cooker must be developed whereby quality of the final edible oil is good and the oil is produced at the lowest possible cost.

Specific recommendations for future study are as follows:

1. The optimum time-temperature relationship of extrusion-stabilization required to provide adequate (possibly up to 3 months) bran stability under tropical conditions should be determined through evaluation of FFA content, oil color, and oil refineability, including studies of: (a) the storage of stabilized rice bran in bags containing traces of unstabilized bran to assure that this does not induce oil deterioration within the stabilized bran; and (b) the effect of microbial contamination, and subsequent adverse effects upon FFA development and/or general oil quality, if any, in a storage test under actual or simulated tropical conditions.

2. Extraction permeability and oil recovery from stabilized bran should be compared with that of pelleted bran. Ordinarily, rice bran must be pelleted before oil extraction. The extrusion-stabilization process, which agglomerates bran particles into large flakes, may not require pelletizing. If so, this would introduce a cost savings into the oil extraction process and a net reduction in overall costs of recovering edible oil.

3. The properties and commercial value of full fat and defatted stabilized bran should be determined and compared with those of unstabilized bran in animal feeding trials.

4. The physical properties and commercial value of crude and refined rice bran oil recovered from stabilized rice bran must be ascertained through (a) chemical quality analyses, including comparison with competing edible oils, and (b) market acceptance studies.

5. Long-term field tests must be carried out to verify operational feasibility, including equipment wear, maintenance and labor requirements, and quality control procedures. Such testing must account for different degrees of milling (that is, bran of variable oil content).

6. Systems other than extrusion cooking have been proposed and used to stabilize rice bran as a prerequisite to recovering edible oil; however, no indepth operational and financial assessments have been made of these alternative systems. Since the overall objective is to recover edible oil from an underutilized resource at the most attractive economic terms, a review of available reports and literature on the operational and financial feasibility of alternative stabilization methods should be carried out. The results should be compared with the results of stabilization with extruder cookers, and for systems which appear favorable, further indepth study should be made.

7. Mechanisms for transferring rice bran stabilization technology must be instituted. Such technology transfer must include services required to disseminate information and provide technical assistance, as well as services to keep the technology functioning, including training, equipment manufacturing, and servicing.

8. Socioeconomic impact analysis is required to determine how, and to what extent, a shift away from traditional utilization of rice bran would impact on a region or a country.

Appendix

Rice Bran Stabilization in Burma

We believe Burma is the only country in the world in which rice bran stabilization is practiced on a commercial scale. During a short visit to Burma in the course of this project, the following information was obtained.

Annual paddy production in Burma is about 11.5 million t per year, of which government purchase programs take about 40 percent of the crop, with the balance being utilized at farm and village subsistence levels. Rice mills include both government and private mills. There are 22 rice oil extraction plants and 11 refineries.

Under an Asian Development Bank loan program, Burma has purchased stabilization units for certain mills from which bran transportation to oil extraction plants is most difficult. Thirty-four units, 28 of 300 kg/h and 6 of 600 kg/h, were designed and built by Japan and shipped to Burma. By 1979, all units were reported to be installed, 15 were operating, and others were coming online as personnel could be trained to operate them. The larger units were located in government mills and the smaller units, in private mills. Ordinarily, the bran is furnished to each stabilizer by the mill in which it is located, though occasionally a supplementary supply is necessary to keep the stabilizer operating at capacity.

These stabilizing units are three-stage screw-conveyor types. In the first stage, steam is injected at 95° to 100°C for 3 min. In the second stage, the bran is dried with steam-jacketed heat at 145° to 150°C, countercurrent flow, during a 6-min cycle. In the third stage, the bran is cooled with forced air, which completes the stabilization process. The final moisture content of the stabilized bran is 3 to 4 percent.

Rice bran oil extraction plants currently operate at capacity on both stabilized and unstabilized bran. Data indicate that unstabilized bran entering the extraction plant shows FFA values of not less than 20 percent, whereas stabilized bran shows FFA values of 3 to 5 percent. Thus, the yield of edible oil is substantially higher with stabilization.

Since Burma is an edible oil deficient country and chooses to import oil only in most severe times, the production of edible oil is not necessarily based only on economic considerations but rather is a policy decision. Nevertheless, the yield of edible oil is an important consideration, as is the ability to produce edible oil from local sources. Stabilization assists here greatly, particularly where bran is delivered to the oil extraction plant only after long postmilling delays.

Statistics for Rice Milling and Rice Bran Oil Extraction Plants in India and Egypt (tables 5 to 8)

Table 5.—Rice production, total rice mills, and 2-stage rice mills, India, 1975-76

State	White rice production	Rice mills[1] Total	Rice mills[1] 2 stage
	1000 t	*Number*	*Number*
Andhra Pradesh	6451	11,912	64
Assam	2290	2,732	[2]2,260
Bihar	4848	4,872	123
Gujarat	572	3,727	515
Haryana	624	1,451	253
Himachal Pradesh	124	944	0
Jammu & Kashmir	423	N/A	N/A
Karnataka	2385	N/A	110
Kerala	1357	10,579	7
Madhya Pradesh	3849	5,434	484
Maharashtra	2241	5,931	808
Manipur	276	169	98
Meghalaya	119	22	6
Nagaland	40	0	0
Orissa	4532	3,833	268
Punjab	1445	N/A	554
Rajasthan	222	368	59
Tamil Nadu	5867	13,897	206
Tripura	367	N/A	N/A
Uttar Pradesh	4367	N/A	739
West Bengal	6823	333	242
Andaman & Nicobar Islands	23	162	0
Arunachal Pradesh	60	N/A	N/A
Dadra & Nagar Haveli	11	20	6
Delhi	2	42	0
Goa, Damman & Diu	84	520	0
Mizoram	39	N/A	0
Pondichery	68	211	12
All India	49 509		

[1]N/A, data not available.
[2]Does not include sheller mills.

Table 6.—Solvent extraction units[1] and rice bran processing capacity, India, 1975-76

State	Total solvent extraction units[2]	Processing capacity Oilcake	Processing capacity Rice bran	
	Number	*t/day*	*t/day*	*t/300 days*
Andhra Pradesh	40 (30)	2850	1375	412 500
Assam	2 (2)	75	40	12 000
Bihar	5 (4)	240	145	43 500
Gujarat	43 (4)	4840	220	66 000
Goa	1 (1)	24	20	6 000
Haryana	5 (3)	295	125	37 500
Karnataka	14 (9)	810	345	103 500
Kerala	2 (1)	110	50	15 000
Maharashtra	23 (13)	2815	1195	358 500
Madhya Pradesh	14 (9)	1165	505	151 500
Orissa	5 (2)	218	35	10 500
Punjab	10 (7)	590	285	85 500
Rajasthan	2 (1)	110	40	12 000
Tamil Nadu	7 (4)	405	185	55 500
Uttar Pradesh	15 (8)	1060	365	109 500
West Bengal	5 (5)	365	230	69 000
Total	193 (103)	15 972	5160	1 548 000

[1]Only those units are listed whose owners are members of the Solvent Extractors Association of India.
[2]Figures in parentheses indicate number of extraction units in use as of 1976.

Table 7.—Rice milling statistics (government sector), Egypt, 1974-76

Name of mill	Location	Distance from main mill	Milled rice and brokens[1]	Average milled paddy/year[2]
RASHID MILLS CO.				
		Km	*t*	*t*
Rashid El-Hadith	Rosetta	0	155	30 843
Doma	--do--	1	35	5964
El-Talbany	--do--	1	25	2738
Marzouk	--do--	3	35	[3]1459
Edkou	Edkou	19	120	26 216
Foua El-Hadith	Foua	48	45	10 212
El-Gauhouria	--do--	48	55	10 980
El-Mahmoudia	El-Mahmoudia	50	100	13 430
Total			570	101 842
ALEXANDRIA MILLS CO.				
El-Hadilla	Alexandria	0	105	22 880
El-Masria	--do--	0	90	17 425
Semouha	--do--	3	115	22 715
Moharem Bey	--do--	5	90	17 870
Karmouz	--do--	10	120	22 940
El-Kabbary	--do--	25	120	19 535
Total			640	123 365
BEHERA MILLS CO.				
El-Behera	Damanhour	0	120	27 711
Kafr El Dawar	Kafr El Dawar	38	120	25 048
El Togaria	Zayet Ghazal	4	110	21 135
Abou Hommos	Abou Hommos	18	155	[3]25 033
El-Baharia	Damanhour	2	60	9585
Total			565	108 512
El-Delengal	El-Delengal[4]	20	[5]155	....
KAFR EL-SHEIKH MILLS CO.				
El-Fath	Desouk	0	155	[6]30 361
El-Nasr	--do--	4	85	18 404
El-Hadith	--do--	2	85	20 335
Ragab	Kafr El-Sheikh	32	90	28 546
El-Obour	--do--	31	75	16 018
Beala El-Hadith	Beala	57	155	20 708
Total			645	134 372
SHARKIA MILLS CO.				
Fakous	Fakous	35	155	35 000
Kafr Sakr	Kafr Sakr	35	155	35 000
Zakazik	Zakazik	0	100	20 000
El-Ebrahimea	Ebrahimea	17	70	18 000
El-Fayoum	El-Fayoum	210	75	18 000
Total			455	126 000
GHARBIA RICE MILLS CO.				
Kotour	Kotour	28	155	30 922
El-Nasr	Mehallah	0	150	25 817
Nour El-Din	--do--	0	100	19 762
El-Sawy	--do--	0	100	20 542
Kouper	Zephta	45	70	11 528
Borai	Meet Ghamr	45	50	8773
Sers	Sers El-Layan	85	65	8326
Total			690	125 690

See footnotes at end of table.

Table 7.—Rice milling statistics (government sector), Egypt, 1974-76-Continued

Name of mill	Location	Distance from main mill	Milled rice and brokens[1]	Average milled paddy/year[2]
		Km	*t*	*t*
DAKAHELA RICE MILLS CO.				
Behrend	Mansoura	0	120	23 121
Mansoura	--do--	0	120	22 733
El-Atrely	--do--	2	120	21 967
El-Shennawy	--do--	1	120	21 694
Mansoura	--do--	0	550	6833
Dekernes	Dekernes	25	90	22 414
Kafr Behoul	Kafr Behoul	20	80	13 526
Demshelt	Demshelt	20	40	6009
Total			740	149 297
DAMIETTA & BELKAS MILLS CO.				
Abou Hassan	Belkas	30	80	15 000
Abou El-Fetouh	--do--	30	80	15 000
Shelbaya (B)	El-Manzala	40	80	15 000
Hal	--do--	40	80	15 000
Sherbin	Sherbin	12	100	10 000
El-Zarka	El-Zarka	0	155	35 000
El-Badry	Damietta	30	50	10 000
El-Read	El-Read	15	80	15 000
Total			705	130 000
National totals			5010	999 078

SOURCE Ranjhan, S. K., and E. C. Beagle. 1978. Utilization of rice hulls for animal feeding. Food and Agriculture Organization of the United Nations Bulletin 6/EGY/03/I.

[1]Capacity in 24 h.

[2]3-year average.

[3]For 1 year—not an average.

[4]Under construction.

[5]Projected capacity.

[6]Average taken over 2 years.

Table 8.—Rice bran oil extraction plant statistics, Egypt, 1978

Locality	Company name	Rice bran: Capacity/ year	Rice bran: Actual production/ year
		----*1000 t*----	
Alexandria	Extracted Oils Co.	25	20
Kafr El-Sheikh	Alexandria for Oils & Soap	25	20
Maniet Sandoub	Masr for Oils & Soap	20	15
Total		70	55

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