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STABILIZATION OF RICE BRAN WITH EXTRUSION COOKERS, AND RECOVERY OF EDIBLE OIL: A PRELIMINARY ANALYSIS OF OPERATIONAL AND FINANCIAL FEASIBILITY

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SUMMARY

Rice bran, a byproduct of milling paddy 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%, 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%) significantly reduce the value of the oil as a foodstuff. Consequently, most of the oil from the small quantities of rice bran that are currently extracted is used for soap manufacture. The small amount of rice bran oil which is suitable for food is obtained only in those limited situations where it is possible to extract the oil within a few hours after milling so as to keep the accumulation of FFA at low levels. Because industrial oils generally have lower prices than food grade oils, this pattern of utilization results in a lower economic recovery than utilizing rice bran oil for food.

It is possible to slow or stop the rapid bran oil deterioration 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, 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 undertaken to determine preliminarily the operational and financial feasibility of rice bran stabilization bv means of 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 which would impinge upon technical and economic aspect of edible rice bran oil recovery in developing countries. The study focuses on rice milling operations, rice bran oil extraction and marketing of raw and extracted bran and rice bran oil.

Two basic plans are considered for extruder stabilization of rice bran and recovery of edible oil: (1) a centralized stabilizer unit is used to stabilize bran accumulated from a number of neighboring small rice mills, and (2) stabilize units are 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% on the capital investment. Each mill would produce 200-300 MT of stabilized bran per year, or the equivalent of approximately 30 MT per 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% in Egypt or 35% in India. Either large mills or centralized installations would produce about 4,800 MT of stabilized bran per year, or approximately 600 MT per year of edible oil.

It is estimated that systems of these types could lead to the production of as much as 700,000 MT of additional edible oil per year in developing countries.

The feasibility of installation and operation of extruder-stabilizing systems in developing countries has been demonstrated by AID (1). 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 extrusion-cooking technology previously demonstrated by AID. However, this conclusion 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 marketplace with other oils and feeds; and (4) verify that local operating conditions, repairs and maintenance, bran handling, and related 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.

INTRODUCTION

Increased food production is a major focus of development programs in most low income countries. While the primary emphasis of these programs is usually on agricultural development, increased food production can also be derived by reduction in post-harvest losses and improved utilization of available commodites and byproducts. The U.S. Agency for International Development (AID), in its efforts to assist developing counties, has recently supported a number of new initiatives to increase food availability through indirect agricultural approaches. 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 two billion people. World production of paddy in 1979 was 385 million metric tons (MT).

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% 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 (15-18%) 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 fro 4-9% 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 and on 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 18-20 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% 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 which are recovered for use as soapstock or other industrial uses, generally amount to somewhat over twice the amount of free fatty acids present in the oil. Thus, for crude rice bran oil containing 30% free fatty acids, 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, in order to economically recover edible oil.

Crude rice bran oil with free fatty acid levels of over 10% 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 purposes in which free fatty acids 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. However, the time required 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 is the practice in developing countries of milling large quantities of rice in "one stage" (huller) mills which 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%, that it is not economically feasible to extract the oil. However, there is a growing trend toward use of "two stage" rice mills in which bran and hulls are recovered separately.

Although the proportion of rice milled in "two stage" mills varies considerably among countries, it is estimated that not less than 20% of the annual world paddy production is milled in "two stage" milling units. Thus approximately 4.6 million MT 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 MT 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. Recognizing the potential value of recovering edible rice bran oil, scientists 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.

Rice Bran Stabilization

Scientists have found that the deleterious enzymes in rice bran can be detroyed 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 has been found that the enzymes in rice bran containing 30% moisture can be destroyed at temperatures of 90-100°C when held for 5-10 minutes in a steam injected conveyor screw. In bran containing 10% moisture these enzymes can be destroyed in seconds at 130-140°C. The literature (2,3) describes a number of processes which can effectively stabilize rice bran. The oil in rice bran stabilized by these methods does not degrade when stored for several months, and the FFA content essentially remains fixed at the level it was at 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 extrusion-cooker equipment for rice bran stabilization for the following reasons: (1) extrusion-cooking 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 case of steam, finish drying is not required; (3) extrusion-cooking equipment is simple to install and operate as experienced in other AID-supported projects in developing country settings; and (4) extrusion stabilization 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. It has been reported (4) 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. It is anticipated that extruder cooking of bran likewise would 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 (ca. 1.5%), which should be removed if the oil is to find use 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 comparble to those of other high quality food oils, and its principal food uses would be expected to be 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 which must be addressed in a technology development program for low-income 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 in 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 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 MT or less of paddy per hour whereas larger mills sometimes mill up to 8 MT of paddy per hour. Oil extraction plant capacities, bran and food oil prices, and labor and energy costs, differ between countries.

Because of the diversity of operational techniques and pricing structures, it was deemed essential that specific country situations must be considered individually in order 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 in-country analysis because they represented diversified milling operations, different price structures, government and private ownership, and different climatic environments. Also, they were 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[1]

India, which operates more or less on a free market pricing system with only minimal governmental price structuring, produced about 80 million MT of paddy in 1979. About 15% of this paddy is milled by two-stage milling, and almost all of this is extracted to recover about 100,000 MT of oil. The Indian oil extraction industry generally anticipates a lag time between milling and extraction of up to several months, in which period FFA development is severe. The oil typically contains 10 - 50% FFA and is predominantly used (95%) as an industrial oil. Oil with less than 7% FFA is generally used in vanaspati (hydrogenated vegetable oil); this use, which is not more than 5000 MT, 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 MT 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 there is capability for oil clarifying and refining, by centrifuging, filtering, caustic treatment, and bleaching, but not for dewaxing which may be essential for a salad 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

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[1] See Appendix

centralized locations might be possible. Furthermore, since the Indian government is actively promoting and financing conversion of single-stage mills to two-stage milling, extractable bran resources will increase in future years.

Egypt[1]

Of the annual paddy production in Egypt (about 2.4 million MT), 40% is milled in the government mills and 60% in the private sector. Two-stage milling (which exists only in the government mills) produces 56,000 MT of bran which is suitable for oil recovery. Eight rice milling companies within the Ministry of Supply operate 54 mills, and mill for 7-8 months a year, handling collectively about 5000 MT 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 production of rice bran oil for soap production in their plants and, presumably, would have little interest in production of 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 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.

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[1] See Appendix

Options for Stabilizer Installation

The basic operational options for installation of rice bran stabilizers are shown schematically in Figures 1A, 1B, and 1C. In 1A, a large centralized stabilizer unit (500 Kg bran/hour) is used to stabilize bran which arrives on a daily basis from a number of small satellite rice mills (100 Kg bran/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 hours. FFA development would thus be at a level sufficient to have only a small adverse effect upon refined oil yield.

In 1B, a large stabilizer obtaining bran from satellite rice mills and located at the oil extraction plant is illustrated.

In 1C, a decentralized operation is illustrated in which large stabilizers (500 Kg bran/hour) are installed at individual rice mills having 6-8 MT paddy/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. Plan 1C could also be used to stabilize rice bran directly at small 2 MT paddy/hour rice mills (100 Kg bran/hour). Stabilizers located at small mills would provide the advantage of less FFA development as compared to 1A with corresponding higher refined oil yield.

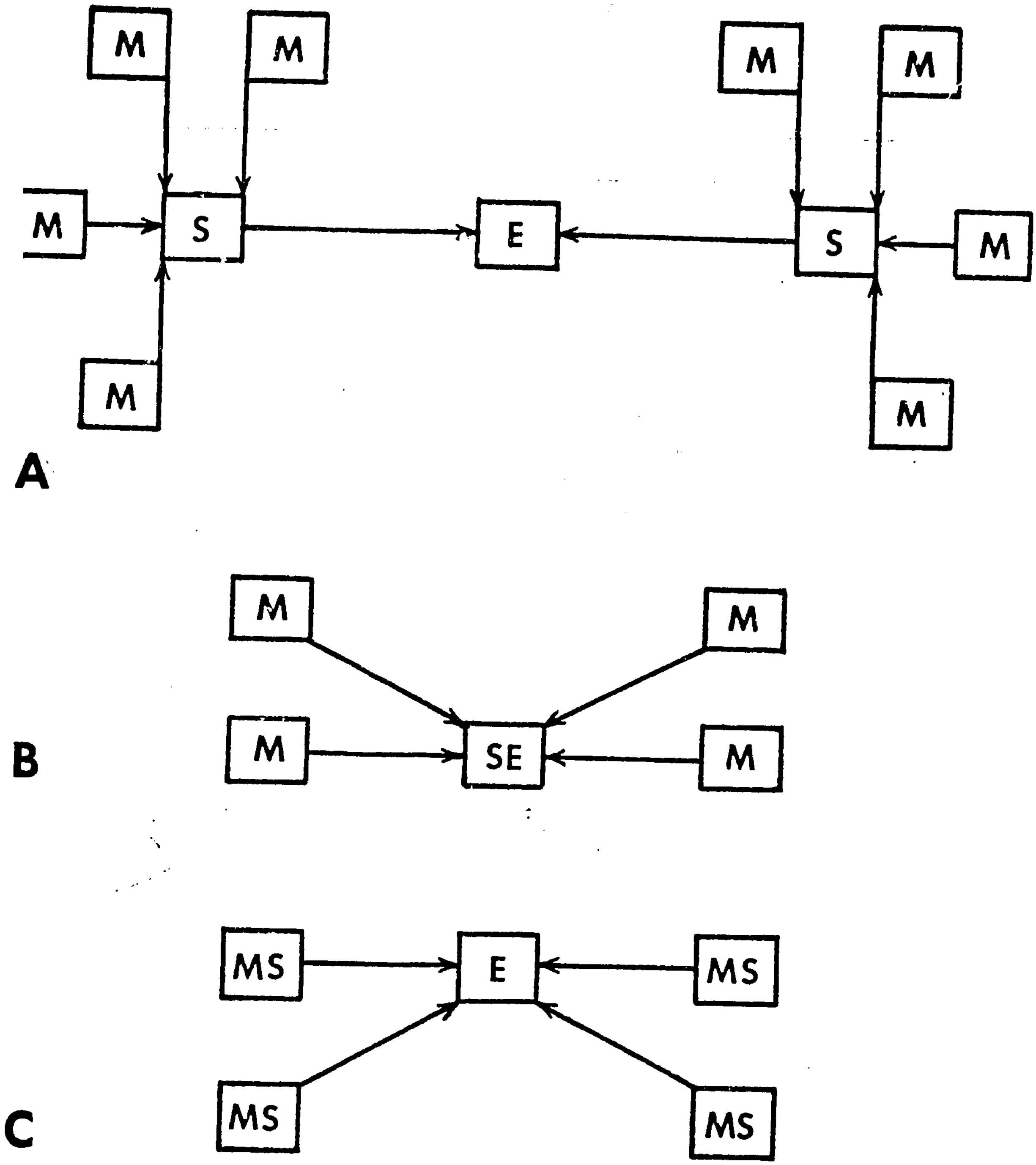

FIGURE 1. Options for installation of rice bran stabilizers
M, rice mill; S, stabilizer; E, oil extraction

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 capacity per hour) or large (500 Kg bran/hr) 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 principle variables on costs and returns on investment for these strategies in India and Egypt are discussed below.

Equipment and Building Requirements

In this analysis it is assumed that 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. It is assumed that evaporative cooling during transfer of the bran on a belt conveyor will be sufficient to prevent excessive color deterioration.

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

Operations When Rice Bran –	
Stabilized at Individual Mills	Stabilized at Central Locations
1-Stabilize and cool rice bran	*1-Bag raw bran, and place in temporary storage
*2-Bag stabilized bran, and place in temporary storage	*2-Sell bagged bran
*3-Sell bagged bran	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, and 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

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

The building for the stabilizing and cooling equipment and the bagging operations and temporary storage of the stabilized bran are assumed to be constructed with concrete floors and reinforced brick walls. In India, adequate space is allowed for storage of about two weeks output of stabilized bran for both the individual and central operations, assuming a 12-hour working day in rice mills. In Egypt, space is provided for about one week's output, assuming a 24-hour workday.

Equipment and building descriptions and estimated investment costs are given in Table 2.

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

With present rice milling operations it is assumed that rice bran is bagged and sold f.o.b. the rice mill, and that 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 it is assumed that 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 it is assumed that the additional labor requirement will consist of one equipment operator and three workers will be required to receive and dump raw bran, to bag the stabilized bran, and to transfer the bags to temporary storage.

Since it is assumed that 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

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/hr	500 Kg/hr
		Dollars	Dollars
Building[1]	Concrete floor and roof with brick walls, reinforced	3,000[2]	12,000[3]
Stabilizer unit[4]	15 h.p. motor	2,400[5]	--
	100 h.p. motor	--	14,055[6]
Conveyor-cooler[7]	3 x 0.3 meters .5 h.p. motor	750	--
	15 x .3 meters 1 h.p. 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 square meters, 3 meters high at cost of $120 per square meter.

3 100 square meters, 3 meters high at cost of $120 per square meter.

4 Includes bran pickup blower conveyor, feed hopper (surge tank), and shipping cost, motors, installation, and contingencies.

5 Includes $1000 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, on mass production of small stabilizer units intended only for rice bran stabilization.

6 Includes $7800 for extrusion-cooker and motor, $500 for bran pickup blower and feed hopper plus 15 percent ($1170) spare parts and 50 percent for freight, installation, and contingencies. Based on 1979 costs of standard extruder available in the commerial market.

7 Includes installation and contingencies.

*Based on exchange rate for India of 1 rupee = $0.128 and for Egypt 1 pound = $1.50.

Table 3. Costs for stabilizing, temporary storage and transportation of rice bran with decentralized and centralized systems. 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	480[8]	6,120[9]	1,200[9]
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	4.00[11]	4.00[11]	5.00[12]
TOTAL	14.28	10.18	14.18

[1] Stabilization at individual rice mills with 100 Kg/hr stabilizer. Plant operates for 240-12 hr days per year and processes 240 tons of rice bran. Assumes 2 hrs down time per day (10 hrs productive time).

[2] Stabilization at individual rice mills with 500 Kg/hr stabilizer. Plant operates 240-24 hr days per year and processes 2400 tons of rice bran. Assumes 4 hrs down time per day.

Footnotes continued on next page.

Table 3. (cont.)

[3]Stabilization is done at central location with 500 Kg/hr stabilizer. Plant collects rice bran from 5 or 6 small mills, operates for 240-12 hr days per year and processes 1200 tons of rice bran per year. Assumes 2 hours down time per 12 hr day.

[4]Based on use-life of 10 years for equipment, 25 years for buildings.

[5]1% of investment cost per year.

[6]$1.00 per ton of bran.

[7]Electricity use is 100 KWH/ton of bran stabilized at $.05/KWH in India and $.015/KWH in Egypt.

[8]One equipment operator to operate and service the stabilizing equipment at $2.00 per day.

[9]Includes one worker to operate and service the stabilizer at $2.00/day ($2.50/8 hr in Egypt), 3 laborers to receive and dump raw bran, bag stabilized bran, sew and move filled bags to temporary storage at $1.00 per day ($2.00/8 hr shift in Egypt).

[10]Assumes cost of interest at 15% 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 ton for loading stabilized bran at rice mill, transporting 60 Km to oil extraction plant and unloading ($1.00 for loading and unloading, plus $1.00 for each 20 Km hauled).

[12]Custom charge per ton for loading bran at rice mill, transporting 20 Km to central stabilizing unit, and unloading,plus loading stabilized bran at stabilizing unit, transporting 40 Km to oil extraction plant and unloading ($1.00 for each loading and unloading, plus $1.00 for each 20 Km hauled).

*Based on exchange rate for India of 1 rupee = $0.128 and for Egypt 1 pound = $1.50.

from India and Egypt indicate that the cost in both countries is $1.00 per ton for each 20 km it is transported. Thus, for centralized stabilization plants, the loading and unloading cost per ton of bran is $2.00 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 ton for stabilizing bran. In India these costs are estimated to be $10.28 per ton for small decentralized plants and $9.18 per ton for large centralized plants. In Egypt, the costs are $6.18 per ton for large decentralized plants. Costs per 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 ton of bran stabilized in the small decentralized plants in India are not a great deal higher (only $0.10 per ton) 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.

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 per ton of bran were reported for plants of about 20 tons per day rice bran extraction capacity. Oil refining and other processing costs of $102.40 per ton 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 is the cost of the raw bran used, plus an allowance for the moisture and other processing losses (about 5%) 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 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 per ton less than the domestic price of raw bran which, in August 1979, was selling for about $95 per ton. 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 per ton in 1979. The effect of these price variations are analyzed below.

Soapstock[1] 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. With regard to the value of soapstock, which is sold for livestock feed and industrial uses, it was assumed that it will be one-half the value of crude, high FFA rice bran oil.[2] The price for crude high FFA rice bran oil in India in 1979 was about $750 per ton; 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 per ton.

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 made in this report.

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1 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.

2 This assumption is based on a communication with the Pacific Vegetable Oil Co., Richmond, California (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.

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

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

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

where:

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

RS_t = Tons of stabilized bran

CO_y = Decimal equivalent of percentage yield of crude oil.

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

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

DB_{pt} = Price per 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 ton.

$$\text{Annual costs} = RS_t\ (RB_{pt} + RS_{ct} + 29.44 + 102.40\ (CO_y) + .05D + L_n)$$

where:

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

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

29.44 = Cost per ton of extracting oil from bran.

102.40 = Cost per 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).

For purposes of this analysis we have made estimates of the "most likely" level for each of the variables 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 the following:

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 (0.1 ton) of stabilized rice bran per hour, located at an individual rice mill operating for 12 hours per day (10 hours productive time), 240 days per 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 (U.S. $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.

System #2. This system is for the oil extraction and refining operation only. It assumes that an oil extractor of 20 tons 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 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

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	tons	0.1	--	2.0[6]	1.0
Annual production[5]	do.	240	--	4,800	4,800
Selling price/ton	dollars	123	--	--	--
Annual sales value	do.	29,520	--	--	--
Edible oil					
Annual production	tons	--	576	576	576
Selling price/ton	dollars	--	1,152	1,152	720
Annual sales value	do.	--	663,552	663,552	414,720
Defatted bran					
Annual production	tons	--	4,080	4,080	4,080
Selling price/ton	dollars	--	80	80	8
Annual sales value	do.	--	326,400	326,400	32,640
Soapstock					
Annual production	tons	--	144	144	144
Selling price/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[5]	do.	24,000	--	480,000	38,400
Stabilized bran	do.	--	590,400	--	--
Stabilization costs	do.	2,647	--	44,040	29,646
Extraction and refining costs	do.	--	215,040	215,040	215,040
Transportation costs	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

Footnotes on next page.

Table 4 (cont.)

[1]Assumes that stabilizer unit is located at each rice mill and that 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 per ton to yield this return.

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

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

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

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

[6]Requires four stabilizers producing 0.5 tons stabilized bran each per hour and operating 2400 hours per year.

[7]Requires two stabilizers producing 0.5 tons stabilized bran each per hour and operating 4800 hours per year.

assumption that the price of refined rice bran oil would be equal to sesame oil, that the price of defatted bran would be 80 percent of the price of raw bran (assumed to be $100 per ton 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 per ton at the time of the survey.

The estimated investment for an oil extraction-refinery operation with a capacity of 20 tons rice bran per day was derived from from Pe (5) 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 it is assumed that this investment would be double for 1979.[1] It is also assumed the plant operates for 24 hours per day (20 hours productive time), 240 days per 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 4 extruder cookers, each with a capacity of 500 Kg (0.5 tons) stabilized rice bran per hour operating for 12 hours per day (10 hours productive time), 240 days per year, integrated with and managed by an oil extraction-refinery with a capacity of 20 tons 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 hours per day (20 productive hours), 240 days per year, integrated with an oil extractor-refinery as described under systems #2 and #3. Sales prices for products are different for Egypt than in India as indicated in Table 4.

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1 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.

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 a low of 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.

For purposes of evaluating these results, it can be 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 appears to be financially sound while it is 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, it seems likely that the projected return of 23% might be sufficient incentive, particularly in light of 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, there are possible ranges in the key variables that could have a sizeable 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 in 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% FFA (equal to 10% soapstock) immediately after milling, and that FFA increases about 5% per day, the effect of time lapse before stabilization is shown in Figure 2 for rice bran yielding 15 percent and 18 percent crude oil. For rice bran yielding 15 percent crude oil and with a lapse of one day (assumed to be 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 two 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 two days, but would be of questionable profitability at lower yields.

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 post-milling stabilization. The return on investment shown ranges from 15.5

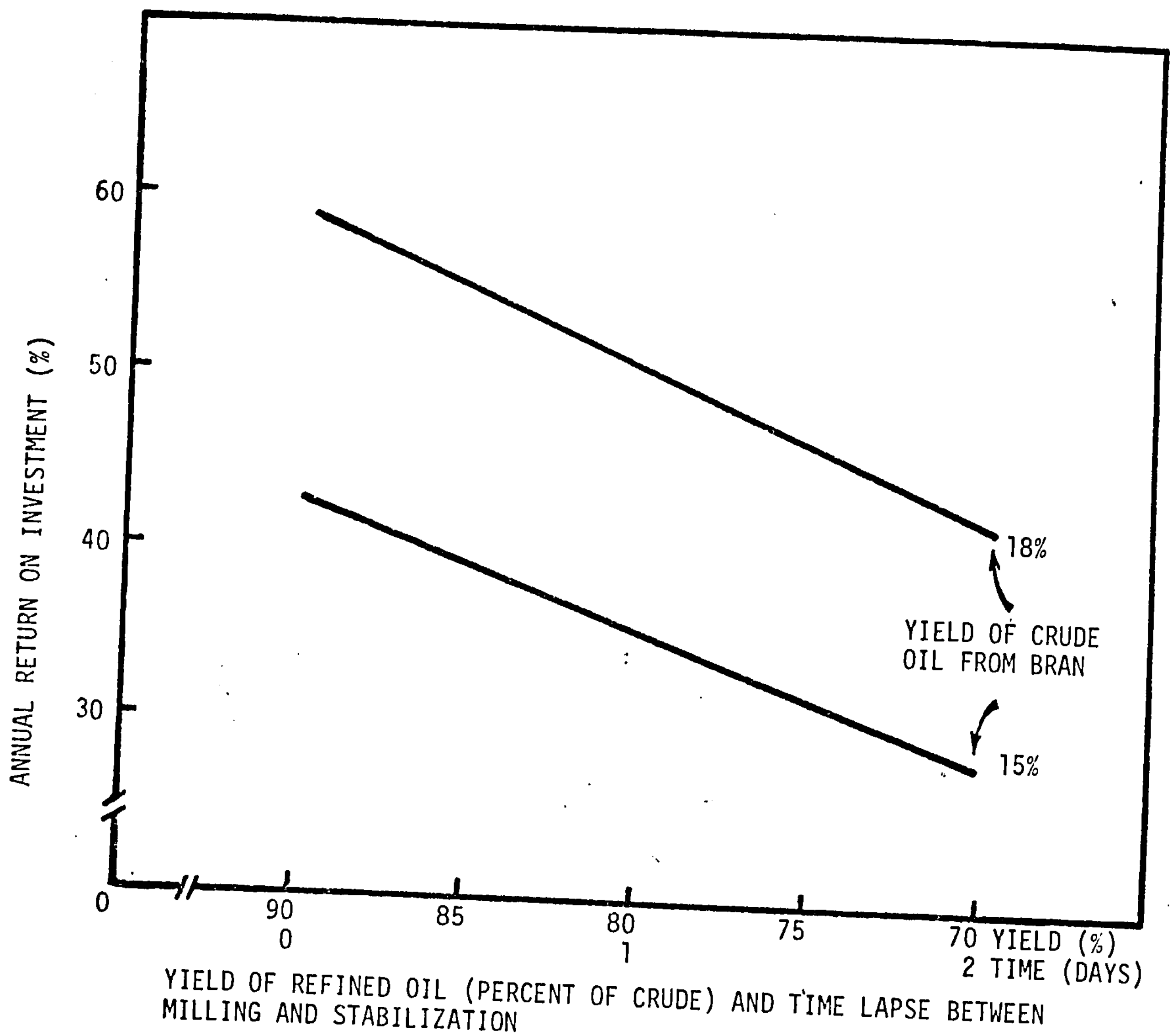

FIGURE 2. Effect of time between milling and stabilization of rice bran and oil yield on annual return on investment, India 1979

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

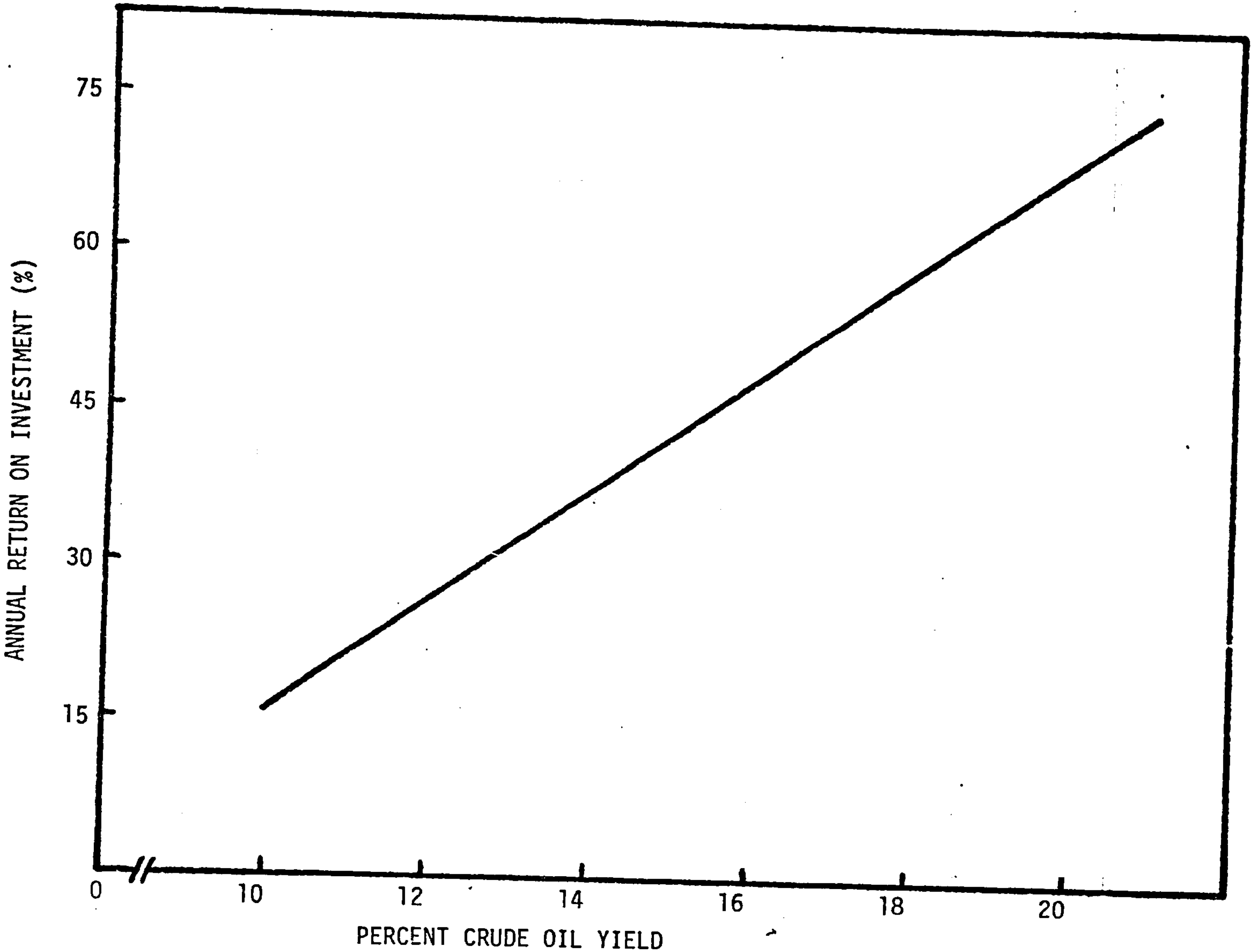

FIGURE 3. Effect of crude oil yield from stabilized bran on return on investment, India, 1979

Assumptions: Centralized stabilization (System #3). Yield of refined oil from crude is 90%; raw bran sells for $100/MT, defatted bran for $80/MT; price of refined rice bran oil is equal to sesame oil ($1152/MT)

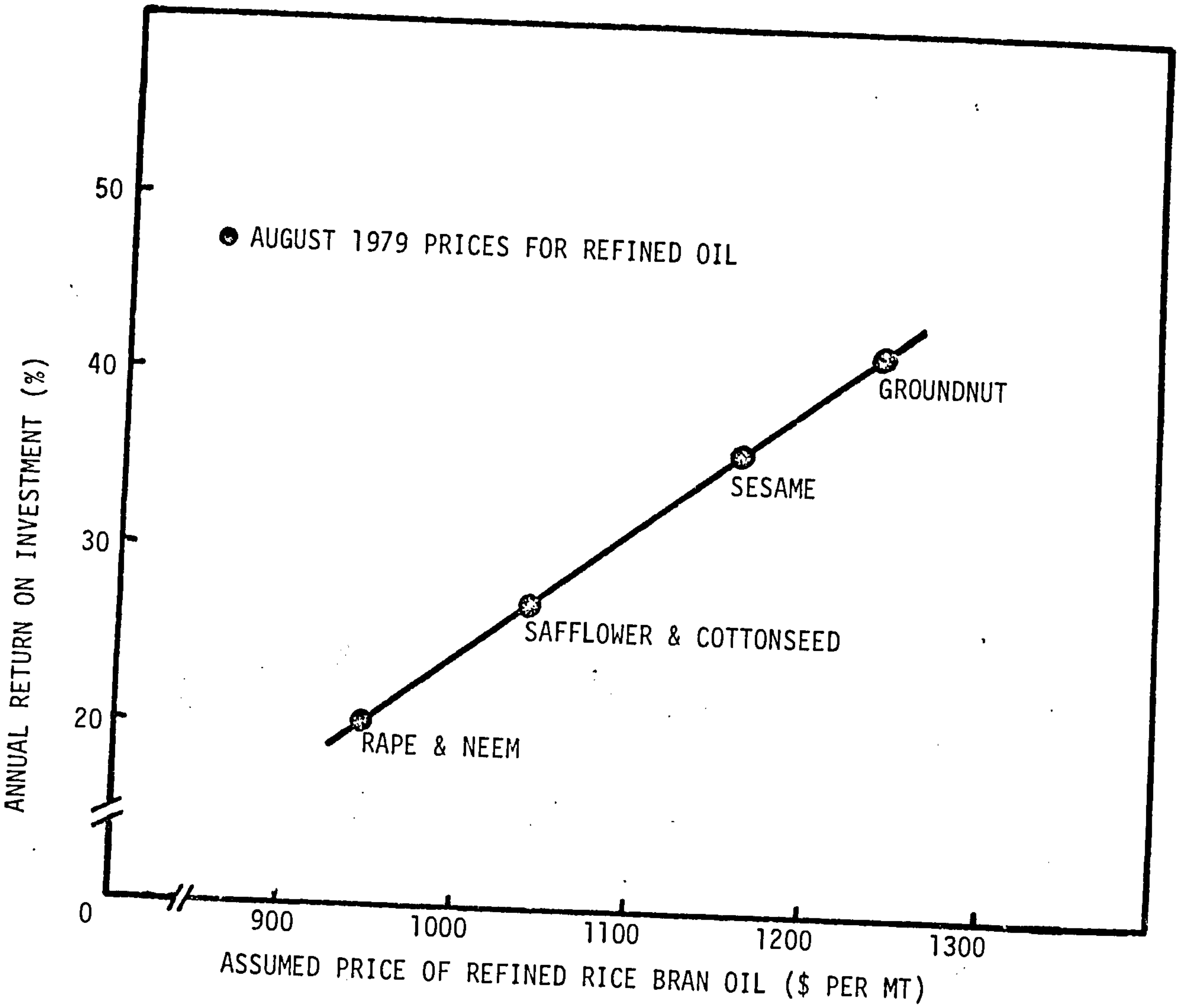

FIGURE 4. Effect of price received for refined rice bran oil on return on investment, India 1979

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

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 per ton, (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 $940 per ton (the price for rape and neem oil), to over 41 percent if the selling price was $1235 per ton (the price for groundnut oil). At a price for refined oil of about $900 per ton, and the other conditions assumed, the return on investment would be too low to be satisfactory. At a price of $1100 per ton 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% or more of the price of sesame oil, or roughly 87% 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 per ton (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 changing the rate for electricity on return on investment. For system #1 (stabilizer only) when the cost used for electricity was 5.0 cents per KWH, the return is 50 percent on investment when the price of

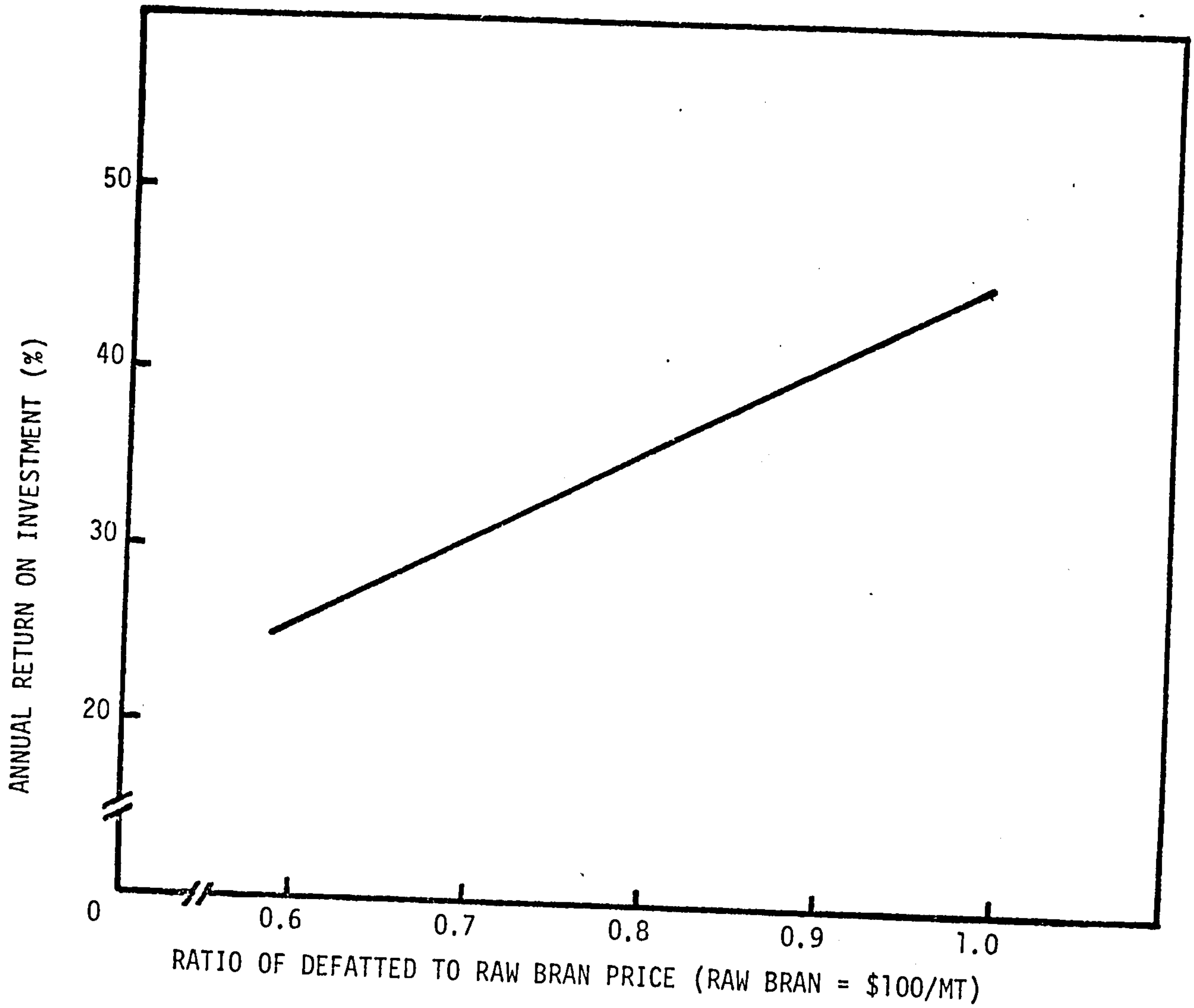

FIGURE 5. Effect of the comparative value of raw and defatted bran on return on investment, India 1979

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

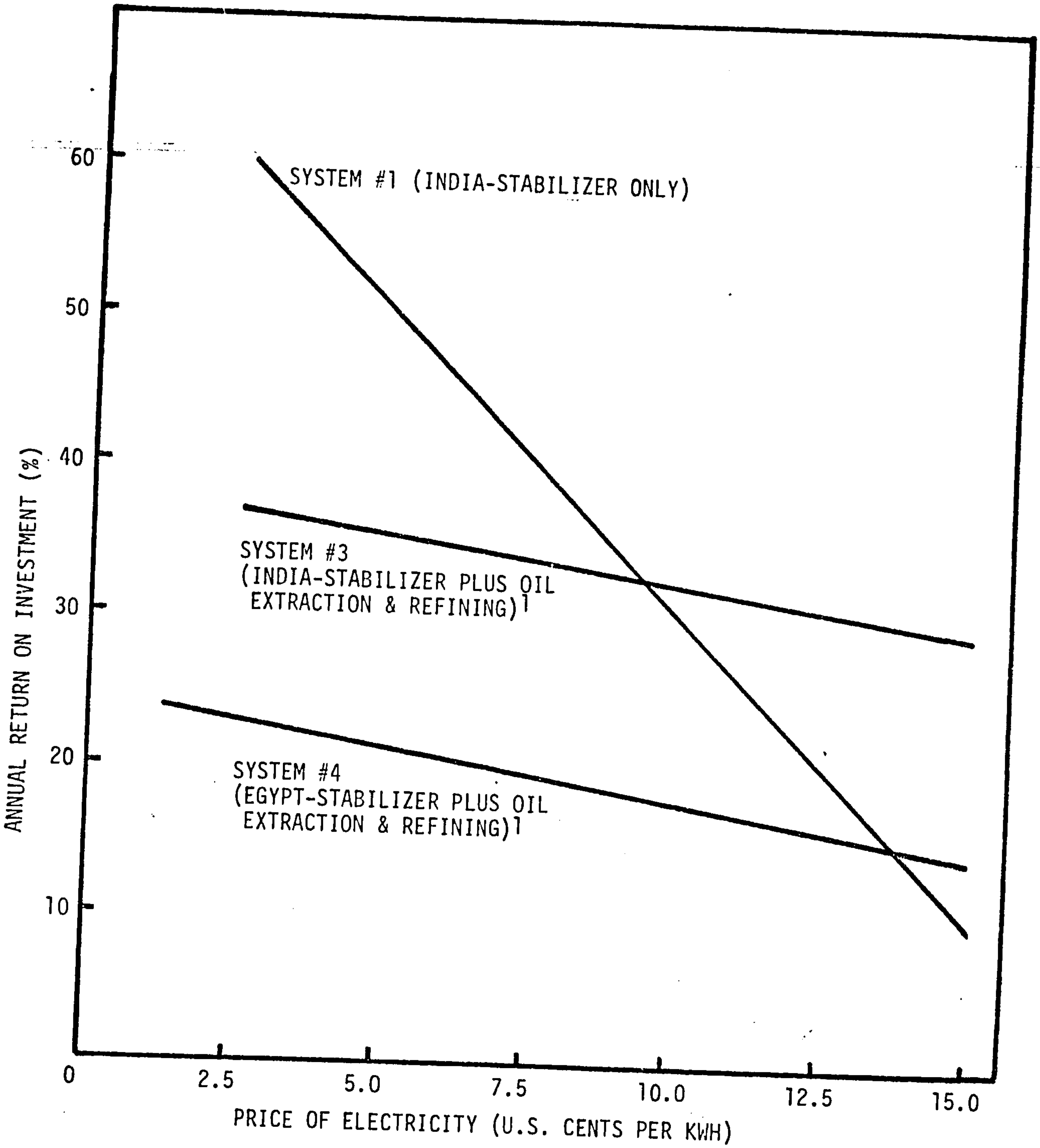

FIGURE 6. Effect of the cost of electricity on return on investment, 1979

Assumptions: See Table 4 for description of Systems

[1]Assumes change in price of electricity for operation of stabilizer only

stabilized bran is $123 per ton. 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 2.5 cents per KWH to 10 percent when the rate is 15.0 cents. For system #3 (India) and system #4 (Egypt) the effect shown is not as dramatic because changes in the rate for electricity are applied only to the electricity used for operating the stabilizer and not for the oil extraction and refining operations. It can be concluded from this analysis that in locations where the rate for electricity is high, serious consideration should be given to methods of stabilization which utilize a heat source other than electricity.

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 sizeable increase in investment (nearly 2X) 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 range in 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.

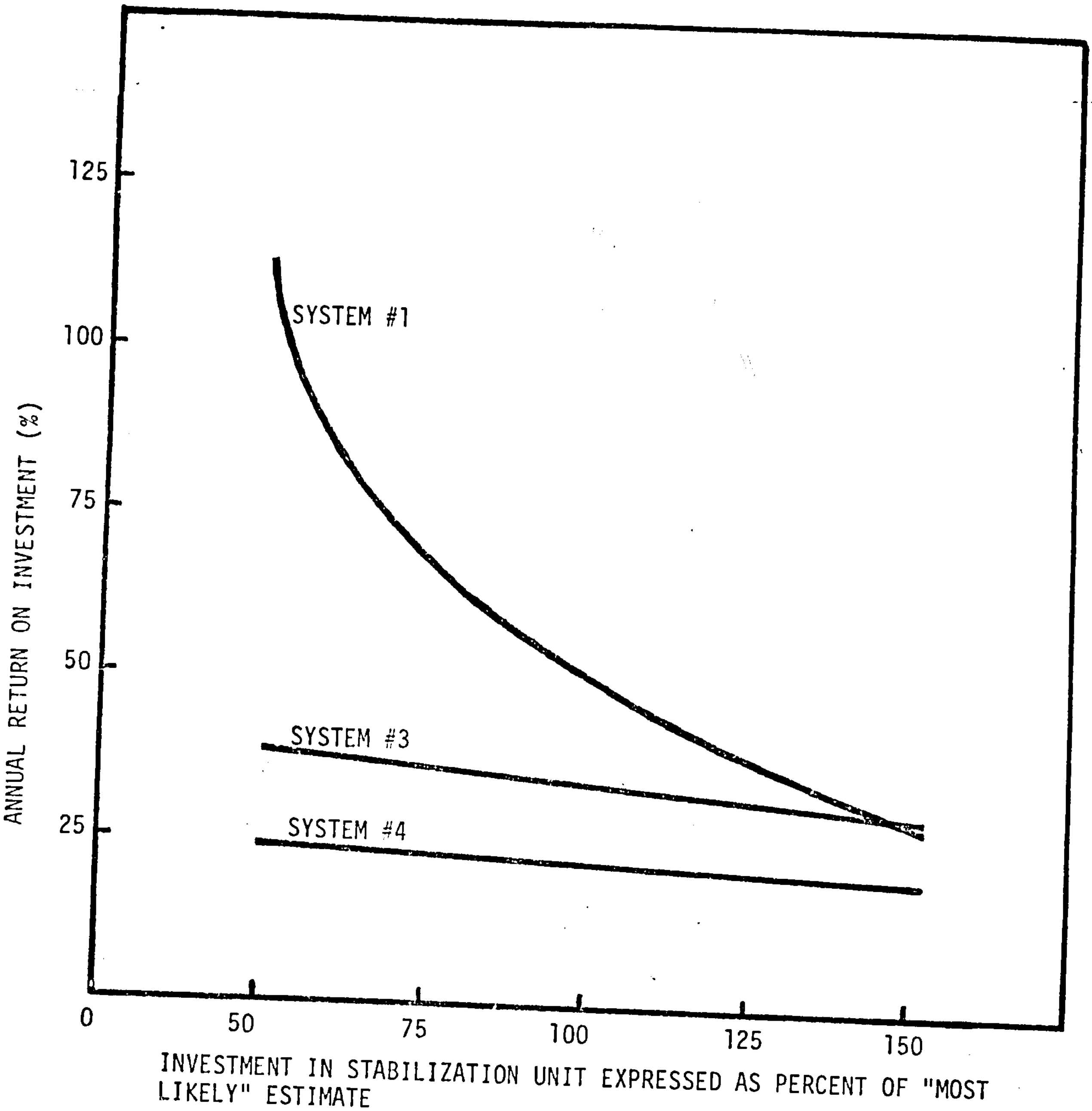

FIGURE 7. Effect of cost of stabilization unit on return on investment in rice bran stabilization followed by oil extraction and refining, India 1979

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

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% return on investment. Each mill could produce about 200-300 MT per year of stabilized rice bran, or indirectly, 30 MT of edible oil. Installation of extruder stabilizers 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 yield a return on capital investment of 23% in Egypt and 35% in India. Depending on annual hours of operation, stabilizers at large mills or at centralized locations would produce 1200-2400 MT per year of stabilized bran, equivalent to 150-300 MT 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/hr. extrusion-cooker. While it appears likely that an extrusion-cooker of appropriate size and cost to permit adequate returns to the miller can be developed, at this time design and development of new equipment is not recommended. It is recommended that the technical and economic feasibility of extrusion-cooker stabilization be first verified through adequate field testing of commercially available larger extruders. If these tests are conclusively positive, smaller extrusion-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 extrusion 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; (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 to that of pelleted bran. Ordinarily, rice bran must be pelleted before oil extraction. It is possible that the extrusion-stabilization process, which agglomerates bran particles into large flakes, may dispense with the need for 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 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 be cognizant of situations in which different degrees of milling (i.e., bran of variable oil content) are encountered.

6. Systems other than extrusion-cooking have been proposed and used to stabilize rice bran as a prerequisite to recovering edible oil. However, no in-depth operational and financial assessments have been made on 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 in-depth 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, etc.

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.

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APPENDIX

1. Statistics for rice milling and rice bran oil extraction plants in India and Egypt are listed in Tables 5 - 8.

2. Rice bran stabilization in Burma.

The authors of this report believe that Burma is the only country in the world in which rice bran stabilization is practiced on a continuous commercial-size basis. 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 MMT per year, of which government purchase programs take about 40% 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 bran 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/hour and 6 of 600 Kg/hour, were designed and built by the Japanese (Yokochi and Musashi Koki) and shipped to Burma. Pe (Burma, 1979) states all have been installed, 15 are operating, and others are coming on line as personnel can be trained to operate them. The larger units are 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. Direct steam injection at 95-100°C for 3 minutes is carried out in the first stage; drying is accomplished by application of steam-jacketed heat at 145-150°C, counter-current flow, during a 6-minutes cycle in the second stage; and cooling with forced air in the third stage completes the stabilization process. The final moisture content of the stabilized bran is 3-4%.

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 not less than 20%, whereas stabilized bran shows FFA values of 3-5%. Thus, the yield of edible oil is substantially higher where stabilization has been employed.

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 in areas where bran is delivered to the oil extraction plant only after long post-milling delays.

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

State	White Rice Production ('000 MT)	Number of Rice Mills	
		Total Mills	Two-stage Mills
Andhra Pradesh	6,451	11,912	64
Assam	2,290	2,732	2,260[1]
Bihar	4,848	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	2,385	N/A	110
Kerala	1,357	10,579	7
Madhya Pradesh	3,849	5,434	484
Maharashtra	2,241	5,931	808
Manipur	276	169	98
Meghalaya	119	22	6
Nagaland	40	0	0
Orissa	4,532	3,833	268
Punjab	1,445	N/A	554
Rajasthan	222	368	59
Tamil Nadu	5,867	13,897	206
Tripura	367	N/A	N/A
Uttar Pradesh	4,367	N/A	739
West Bengal	6,823	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]Does not include sheller mills.

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

State	Total No. of Solvent Extraction Units[2]	Oilcake Processing Capacity Per Day (MT)	Rice Bran Processing Capacity Per Day (MT)	Rice Bran Processing Capacity Per Yea (300 days) (MT)
Andhra Pradesh	40 (30)	2,850	1,375	412,500
Assam	2 (2)	75	40	12,000
Bihar	5 (4)	240	145	43,500
Gujarat	43 (4)	4,840	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)	2,815	1,195	358,500
Madhya Pradesh	14 (9)	1,165	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)	1,060	365	109,500
West Bengal	5 (5)	365	230	69,000
TOTAL	193 (103)	15,972	5,160	1,548,000

1 Only those units are listed which are members of the Solvent Extractors Association of India.

2 Figures in parentheses indicate number of extraction units which currently extract rice bran.

Table 7. Rice Milling Statistics (Government Sector), Egypt, 1974-1975-1976

Key to Map	Name of the mill	Location	Distance From Main Mill (Km)	Capacity 24 HR Milled Rice + Brokens MT	Av. milled Paddy/Year 3 Years Av. MT
	RASHID MILLS CO.				
7	Rashid El-Hadith	Rosetta	0	155	30,843
9	Doma	Rosetta	1	35	5,964
8	El-Talbany	Rosetta	1	25	2,738
10	Marzouk	Rosetta	3	35	1,459[1]
11	Edkou	Edkou	19	120	26,216
12	Foua El-Hadith	Foua	48	45	10,212
13	El-Gauhouria	Foua	48	55	10,980
14	El-Mahmoudia	El-Mahmoudia	50	100	13,430
	Total			570	101,842
	ALEXANDRIA MILLS CO.				
2	El-Hadilla	Alexandria	0	105	22,880
1	El-Masria	Alexandria	0	90	17,425
3	Semouha	Alexandria	3	115	22,715
4	Moharem Bey	Alexandria	5	90	17,870
5	Karmouz	Alexandria	10	120	22,940
6	El-Kabbary	Alexandria	25	120	19,535
	Total			640	123,365
	BEHERA MILLS CO.				
15	El-Behera	Damanhour	0	120	27,711
19	Kafr El Dawar	Kafr El Dawar	38	120	25,048
17	El Togaria	Zayet Ghazal	4	110	21,135
18	Abou Hommos	Abou Hommos	18	155	25,033[1]
16	El-Baharia	Damanhour	2	60	9,585
	Total			565	108,512
20	El-Delengal	El-Delengal	20	155[3]	

See page 48 for footnotes.

Table 7. (cont.)

		KAFR EL-SHEIKH MILLS CO.			
21	El-Fath	Desouk	0	155	30,361[2]
22	El-Nasr	Desouk	4	85	18,404
23	El-Hadith	Desouk	2	85	20,335
24	Ragab	Kafr El-Sheikh	32	90	28,546
25	El-Obour	Kafr El-Sheikh	31	75	16,018
26	Beala El-Hadith	Beala	57	155	20,708
	Total			645	134,372
		SHARKIA MILLS CO.			
35	Fakous	Fakous	35	155	35,000
36	Kafr Sakr	Kafr Sakr	35	155	35,000
34	Zakazik	Zakazik	0	100	20,000
37	El-Ebrahimea	Ebrahimea	17	70	18,000
38	El-Fayoum	El-Fayoum	210	75	18,000
	Total			455	126,000
		GHARBIA RICE MILLS CO.			
30	Kotour	Kotour	28	155	30,922
27	El-Nasr	Mehallah	0	150	25,817
28	Nour El-Din	Mehallah	0	100	19,762
29	El-Sawy	Mehallah	0	100	20,542
31	Kouper	Zephta	45	70	11,528
32	Borai	Meet Ghamr	45	50	8,773
33	Sers	Sers El-Layan	85	65	8,326
	Total			690	125690
		DAKAHELA RICE MILLS CO.			
39	Behrend	Mansoura	0	120	23,121
40	Mansoura	Mansoura	0	120	22,733
41	El-Atrely	Mansoura	2	120	21,967
42	El-Shennawy	Mansoura	1	120	21,694
43	Mansoura	Mansoura	0	550	6,833
44	Dekernes	Dekernes	25	90	22,414
45	Kafr Behoul	Kafr Behous	20	80	13,526
46	Demshelt	Demshelt	20	40	6,009
	Total			740	149,297

See page 48 for footnotes.

Table 7. (cont.)

		DAMIETTA & BELKAS MILLS CO.			
47	Abou Hassan	Belkas	30	80	15,000
48	Abou El-Fetouh	Belkas	30	80	15,000
49	Shelbaya(B)	El-Manzala	40	80	15,000
50	Hal	El-Manzala	40	80	15,000
51	Sherbin	Sherbin	12	100	10,000
52	El-Zarka	El-Zarka	0	155	35,000
53	El-Badry	Damietta	30	50	10,000
54	El-Read	El-Read	15	80	15,000
	Total			705	130,000
NATIONAL TOTALS				5010	99,9078

[1]For 1 year--not an average.
[2]Average taken over 2 years.
[3]Under construction. Will produce at the end 1979.

Table 8. Rice Bran Oil Extraction Plant Statistics, Egypt, 1978

Locality	Company Name	Rice Bran Capacity/Year 1000 MT	Rice Bran Actual Prod./Year 1000 MT
Alexandria	Extracted Oils Co.	25	20
Kafr El-Sheick	Alexandria for Oils & Soap	25	20
Maniet Sandoub	Masr for Oils & Soap	20	15
	TOTAL	70	55