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LIMITED

ID/WG.89/3 SUMMARY
13 January 1971

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Interregional Seminar on the
Industrial Processing of Rice

SUMMARY

X-M PROCESS FOR SOLVENT EXTRACTIVE MILLING OF RICE [1/]

by

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INTRODUCTION

1. A technology for the solvent milling of rice has been developed and commercially practised for several years by Riviana Foods of Houston, Texas, U.S.A. This technology, trademarked "X-M", is a replacement or substitute technique for the rice-bran removal step of traditional rice milling methods.

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

2. The problems of rice milling are: loss of edible rice, breakage of whole rice kernels, and general under-utilization of the rice-bran product due to its storage instability. By application of X-M processing, these problems are greatly reduced.

PROCESS DESCRIPTION

3. Key steps of the X-M process are the pretreatment of brown rice with rice oil to soften the bran layers prior to milling and milling the rice in the presence of a solvent. With these steps, the bran and germ is removed from the rice kernel under more gentle conditions such that loss of the endosperm is ground away with the bran and the breakage of whole kernels is significantly reduced.

4. Chart I demonstrates the relationship between X-M facilities and conventional rice milling facilities.

5. Chart II gives a simplified flowsheet for the process.

RICE MILLING YIELDS

6. This achievement has been documented by direct comparative test milling between modern conventional facilities and X-M facilities. Over 17,000 metric tons of rice were milled during those tests and the average results show X-M milling to contribute whole kernel rice yield increases of 4-5% and total edible rice yield increases of 1-2%

7. In addition to the edible rice yield milling increases, two by-product streams are obtained. The first is a defatted rice-bran product. The defatted bran (unlike conventional bran) is free flowing, bland in flavor and odor, and stable to storage conditions. This bran has a protein content of 17-20% and is suitable as a human food ingredient.

8. The second product is crude rice oil. This oil is low in free fatty acids (1-2%) because extraction was carried out at the same time as rice milling. Also, the oil has been dewaxed such that it can be processed to quality cooking and salad oils without excessive refining losses.

9. Table I shows Comparative Yields X-M and Conventional Milling.

ECONOMICS

10. Economic feasibility studies show X-M rice milling to be an economically profitable investment when practised as an industrialized manufacturing process Capital cost for a "turn-key" X-M facility with the milling capacity of 100,000 metric tons/year is estimated at 1 to 2 million U.S. dollars. Payout forecasts of this investment are in the range of 4 to 6 years in typical examples. The influence of the specific business environment is highly significant to these calculations and detailed studies are required for each specific case.

11. Capital and operating expenses have been estimated for operations in the Far East based on the capacity of 90,000 metric tons per year of paddy rice. The estimated turn-key capital investment is U.S.$ 1.5 million. The annual operating expenses for labor, hexane, depreciation, supplies, utilities, etc., were estimated at U.S.$330,000 per year, which is equivalent to U.S.$3.66 per metric ton.

12. Table II shows a Summary Economic Statement for the cash flow profitability for operating under the conditions assumed in this case. A payout of 4-5 years is forecast based on a yearly cash flow of U.S.$ 340,000.

13. In summary, a technology for the solvent milling of rice has been developed and commercially proven in the United States of America. This technology offers the benefits of higher yields of milled rice with less kernel breakage, a defatted rice-bran product stream which is storage-stable and high in protein, and the production of a low free fatty acid crude dewaxed rice-bran oil stream. These benefits can be achieved in an economically viable venture when practised as an industrial process in a suitable business environment.

14. The process is protected by patents in most rice producing nations and is available for license through Food Engineering International, Inc. U.S.A.

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Distr.
LIMITED

ID/WG.89/3
14 January 1971

ORIGINAL: ENGLISH

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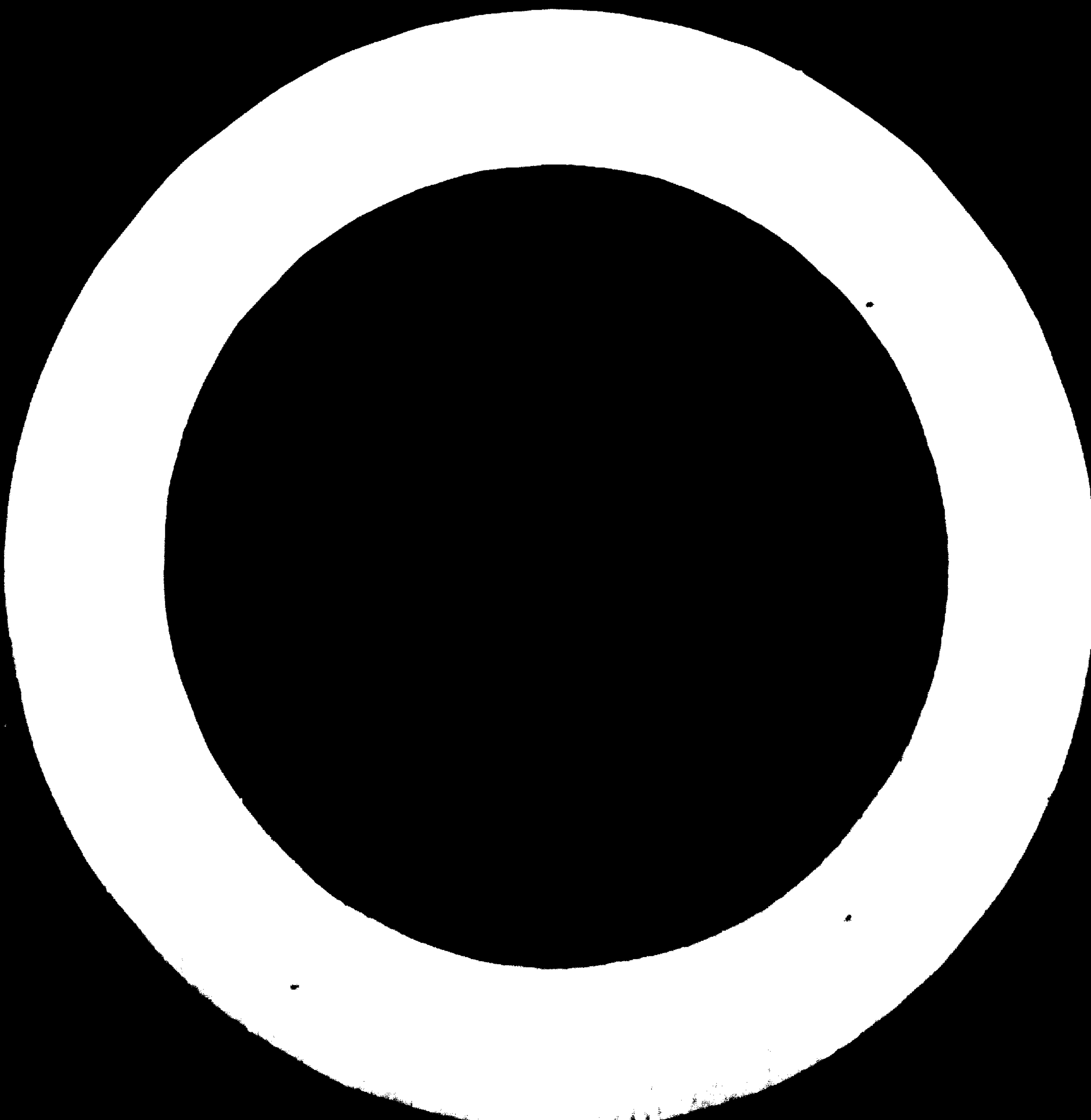


CONTENTS

Introduction

1. Solvent extractive milling is a new technology for rice. This technology is named X-M Rice Milling. Brown rice is the raw material, which is to be processed to white rice with the aim of achieving the highest utilization of that raw material. Rice milling operations have been traditionally plagued with several problems. These problems include (1) excessively grinding away edible rice in the attempt to remove the bran layers, (2) breakage of the whole kernels into less valuable broken rice fractions, and (3) under utilization of the rice bran stream. With X-M rice milling, these problems are controlled by using processing techniques to convert the brown rice to the best possible product mix at maximum yields.

The X-M Concept

2. The concept of X-M is to perform the bran removal function of rice milling under more gentle conditions and in the presence of a solvent to obtain higher yields of rice with less kernel breakage and to extract, during milling, the fatty components from the bran, germ and rice kernel such that high quality by-product streams of defatted rice bran and crude rice oil are obtained. Through this, the usual degradation of these two by-product streams is greatly retarded and the streams become upgraded to co-products with the rice. This technique is more than simple theory. It is commercially proven technology. Riviana Foods Inc., a major rice miller in the United States, has constructed, improved, and operated a commercial scale solvent milling facility for several years. This plant mills approximately 100,000 metric tons of

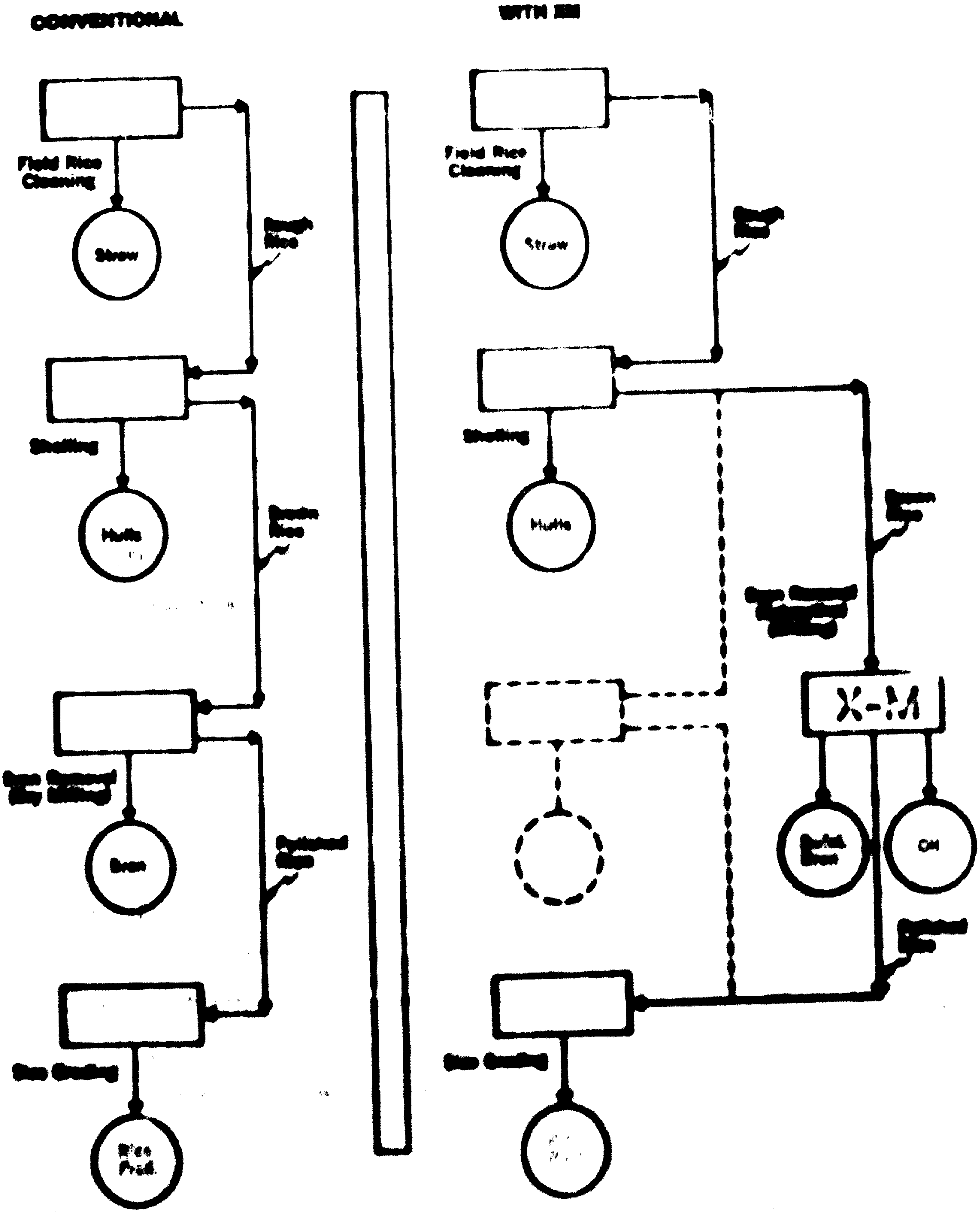
brown rice per year. Hence, rice growing nations around the world have a new tool available to them to increase the utility of their rice crop. This is especially attractive as yields increase and more nations approach or attain self-sufficiency in rice production.

3. The purpose of this paper is to explain the processing techniques that are used to achieve the aims of the concept; to discuss the products and describe their characteristics and markets; to outline the procedures used to substantiate the increased yields in rice milling; and finally, to discuss the economics associated with new ventures in X-M rice milling.

4. Chart I demonstrates the relationship between X-M facilities and conventional rice milling facilities. On the left side, conventional rice processing has been separated into four operations. First, is the cleaning of the field rice to remove dirt and straw. Second, is the shelling step to remove the hulls, which produces the brown rice as a feed stream for the third step of bran removal. Bran, of course, is a by-product from the bran removal step. The edible rice thereby obtained is then forwarded for grading and packaging. When X-M facilities are added, as indicated on the right side, the traditional bran removal step is replaced or substituted with the X-M process. In this case, however, two by-products are obtained from the operation of milling brown rice to white rice. One is a defatted rice bran stream, and the other is a crude rice bran oil stream. The milled rice must still be forwarded to the grading, packaging and warehousing operations. The first and second steps of field rice cleaning and shelling are identical and use the same equipment as conventional milling.

CHART I

RICE MILLING PROCESS OPERATIONS



Commercialization Of X-M

3. Construction of an X-M facility in Abbeville, Louisiana, was initiated in 1964. It was constructed adjacent to an existing conventional rice milling facility. Extensive process and product development activities were conducted from start-up of this operation to the present time. Much of the early development work was centered on the resolution of mechanical problems. Many difficulties were recognized, analyzed, and overcome in the perfecting of this new technology. Among the wide range of experience and knowledge obtained during this development program were (1) satisfactory separation of fine bran particles from the liquid stream by the development and installation of an effective miscella clarification system, (2) various improvements in design and operating techniques of solvent milling machines, (3) development and installation of a crude oil degumming system to produce an oil stream suitable for refining to edible oil, and (4) scale-up of the pilot operations to full-scale commercial production facilities.

Process Description

4. In general, the process is continuous and requires 24 hour per day/seven day per week operation. It does have flexibility with respect to the rice stream in that the milling itself can be stopped and started, as with conventional facilities, and the degree of milling can be adjusted and controlled continuously. Except for the mills, all the equipment is more or less standard equipment, that is, it is available from vendors without custom design. The mills themselves are rotor and stator frictional type horizontal rice mills which have been

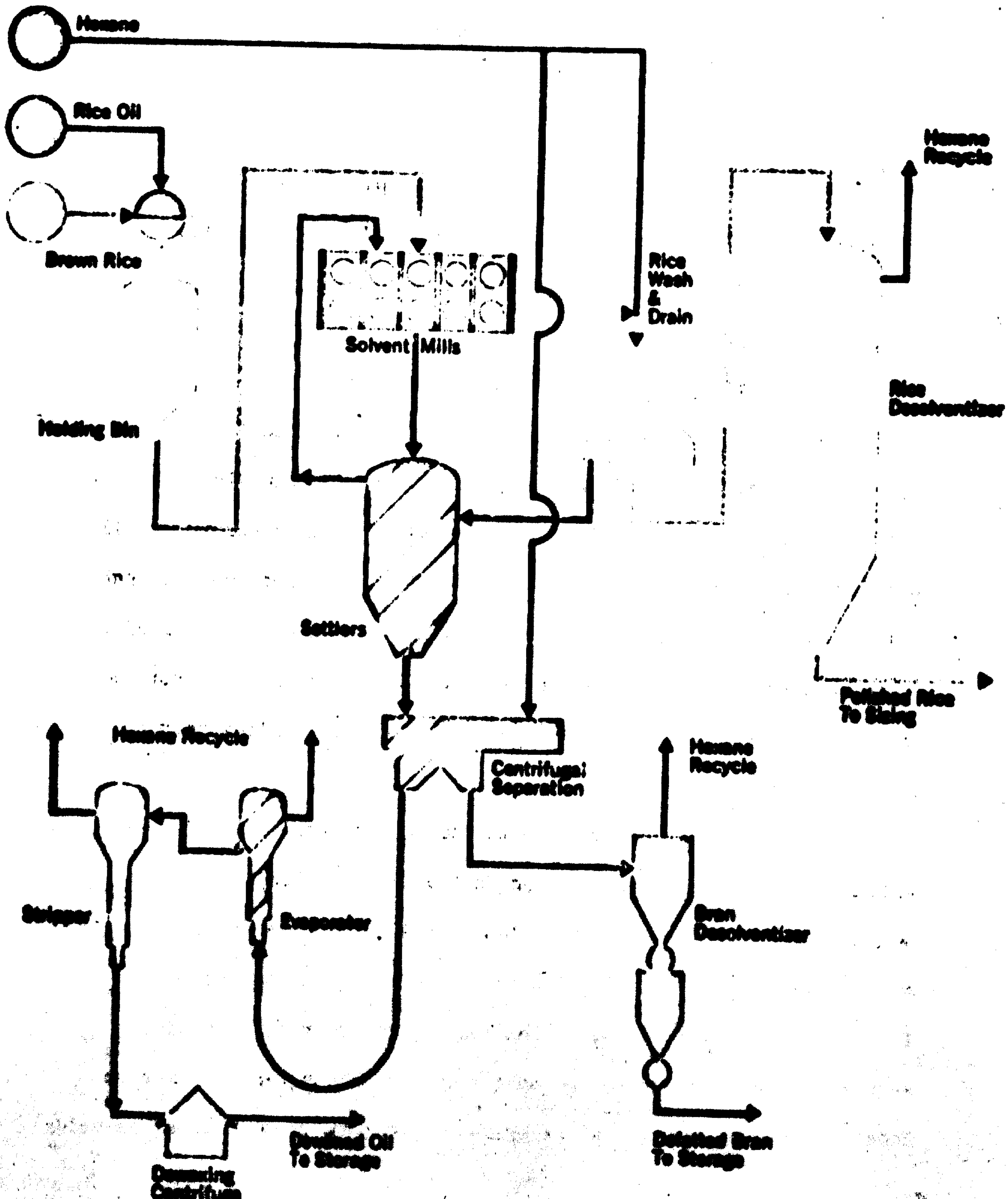
modified to receive and distribute the solvent stream. Since solvent is used throughout the plant, it's necessary to use good operating practices like those for any plant with explosion hazards. The plant should be isolated from ignition sources and explosion-proof electrical equipment is installed in a manner typical of oil seed extraction plants.

7. Chart II gives a simplified flowsheet for the process. The starting point is brown rice coming into the plant. The brown rice has been cleaned of paddy prior to delivery to the plant. After weighing, it passes through a chamber in which warm rice oil is sprayed on the grains at a concentration of approximately one-half of 1%. From here it is conveyed to one of two holding bins. The purpose of this oil treatment and holding is to achieve a softening of the bran layers prior to milling. The treated rice is then distributed to a bank of 24 solvent rice mills. These mills are arranged in parallel such that the rice is milled on one pass, that is, rice goes through only one machine one time for bran removal. A second stream is also introduced to each of the solvent mills. This is a miscella stream made up of rice oil and hexane, such that the rice milling occurs in a liquid miscella medium.

8. We are able to mill the rice to the desired degree of milling with much less pressure than in conventional facilities. This is because of the influence of the liquid milling and the presoftening of the bran coats. The liquid serves as a heat sink to absorb frictional heat thereby preventing heating of the rice. It also serves a lubricating function and a flushing action tends to remove loosened bran particles that otherwise would require mechanical abrasion

CHART II

XM RICE MILLING PROCESS FLOWSHEET



for their complete detachment. In addition, the liquid tends to reduce local pressure gradients such that more even pressure is distributed throughout the rice bed being milled. Time in the milling chamber is approximately 15 seconds.

9. Rice is discharged from the end of the mill and conveyed to a series of vibrating screens in which it is drained and flushed with fresh hexane to remove the surface oil and adhering bran particles. After draining of this wash stream, the rice is conveyed to a desolventizer. The desolventizer is a vertical tower in which the rice cascades from the top to the bottom through two sections. During this period of time, the residual liquid hexane is evaporated by the counter-current flow of a warm gaseous mixture of inert gases and solvent vapors. The desolventized rice is conveyed to the conventional facilities for the appropriate grading, removal of brokens, classification, or packaging steps.

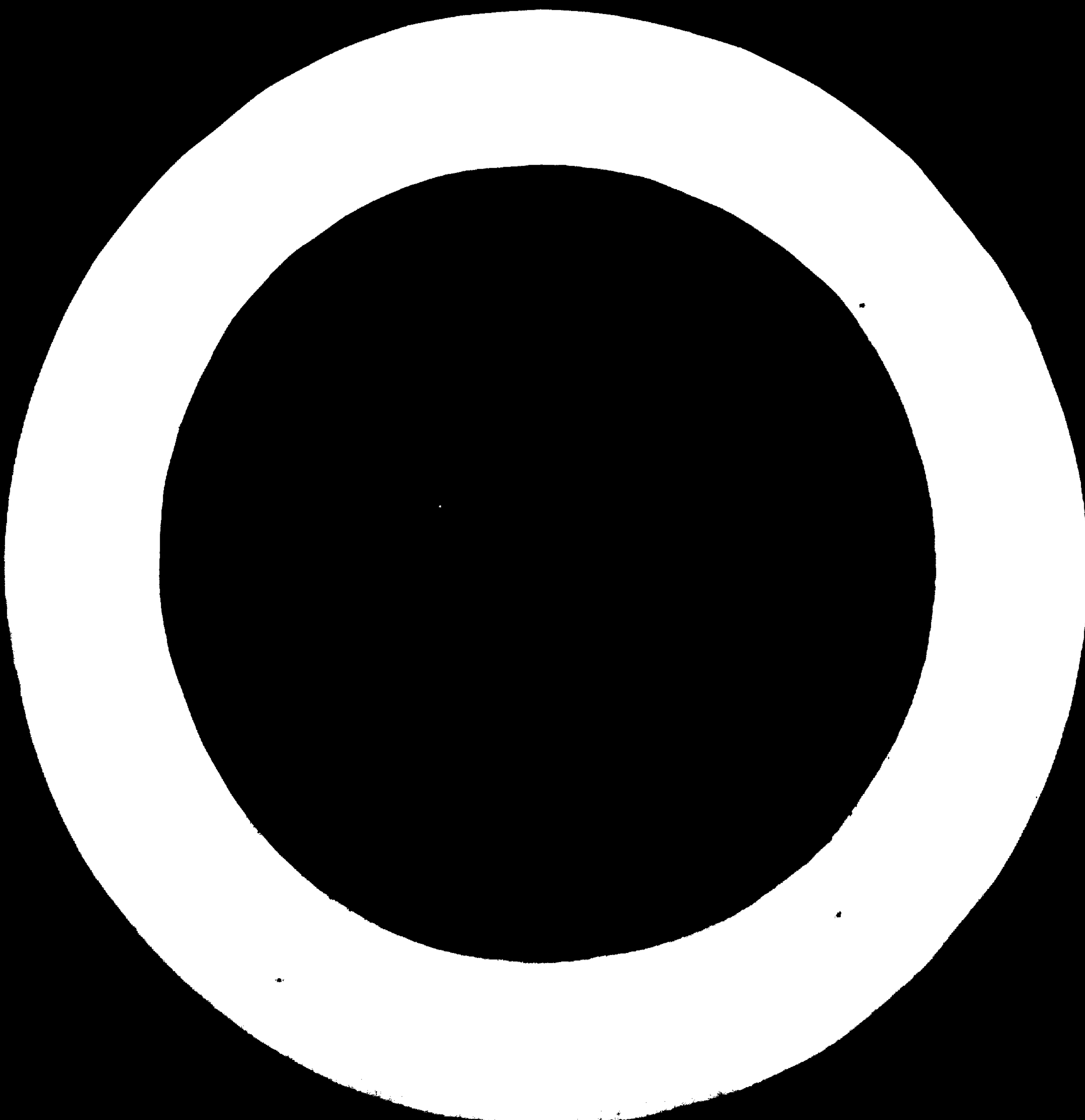
10. The second stream coming from the rice mills is a mixture of hexane and rice oil and bran. Several steps are required to achieve completion of bran extraction and separation of the liquid from the solid streams. A slurry of bran and miscella is deposited to a settler. This settler also receives the liquid from the rice washing as well as several recycle streams not shown on this diagram.

11. Extraction of the oil from the bran as well as the concentration of the bran stream is achieved in this settler. A thickened slurry of bran is removed from the settler and processed through two horizontal centrifugals. Dilution of the miscella and washing of the bran is included prior to feeding the second centrifugal. A hexane damp bran

cake is obtained from the last centrifuge and desolventized with cyclone equipment utilizing super heated hexane vapors and an inert gas purge. The desolventized bran is pneumatically conveyed to bagging and/or storage areas.

12. Rice oil is recovered from the first bran centrifuge liquor. This miscella still contains some bran solids and approximately 11-14% oil plus some rice oil waxes. A series of liquid cyclones is used to remove the larger bran particles. The miscella is then cooled, water is added, and the stream is passed through a high gravity stacked-disc type centrifuge. This centrifuge removes the remaining bran solids and part of the waxy fraction in the oil. This clarified miscella is then distilled with standard stripper-evaporator equipment to remove the hexane from the oil. The hot crude oil containing about 1½% wax, is chilled and stored for 2 days. The long residence time is to allow crystal formation and growth. After holding, the oil is pumped to a mixing station where a floccing agent is added. This agent forms a physical-chemical bond with a precipitated wax to weight the particles for easier centrifugal separation. When centrifuged in a classical, continuous vegetable oil refining type centrifuge, a product oil with very low wax levels is obtained. This crude oil dewaxing is necessary to obtain an acceptable product oil for low-loss vegetable oil refining.

13. Hexane vapors gathered throughout the plant are condensed with water cooled condensors and combined in a central hexane tank for appropriate redistribution. Vapors from the water condensors are vented through a mineral oil absorption system to trap the residual hexane and allow escape of non-condensibles from the plant.



X-M milled rice. These advantages have been achieved without changes in the cooking or eating qualities compared to regularly milled rice. This has been confirmed through blind preference testing by both United States and Philippine consumers. Hence, the markets for X-M milled rice are the same as with conventionally milled rice. Both well milled and intermediate grades are sold through the same channels as conventionally milled rice.

17. The X-M defatted rice bran is a markedly different product from conventional rice brans. This material is free-flowing, it has a bland flavor and odor, a light color, and (with the oil having been extracted) it is stable such that it can be stored and distributed. Chemical analyses indicate new uses for rice bran at potentially higher sales values. The fat content is reduced to 1-2%. The protein content is typically 18-20%. This protein can be precipitated and recovered. We have also demonstrated that the 8% fiber in the bran can be redistributed by rather simple means to yield two bran products, one containing 12% fiber, the other containing 4% fiber. At present, the defatted rice bran is sold to the traditional animal feed outlets, primarily for pelleting for poultry and cattle feeds. With these markets we are achieving the same prices as with conventional rice brans. A small fraction of our sales goes as a human food ingredient at considerably elevated prices. These uses, at present, are in specialty bread flours and as spice carriers. The potential for expanding defatted rice bran as a human food ingredient should be very great in those high rice consuming nations where the need is not being presently filled by other agricultural by-product streams.

18. The characteristics of the X-M crude rice oil are, like the bran, extremely improved compared to traditional supplies of extracted crude rice bran oil. The free fatty acid content is at the 1-2% level and the wax has been removed to the 0.15% level.

19. With these low free fatty acid and wax levels, the crude rice bran oil can be processed to a cooking and salad oil, with losses more comparable to other oil seeds as opposed to the traditionally excessive losses experienced with rice oil. The plant in Abbeville, Louisiana, produces over 3 million pounds per year of oil. This oil is sold to refiners for processing into cooking and salad oils and to various food operations for bread pan release agents and dairy foods. Other markets are for non-food uses such as drilling muds, paints, and protective coatings. Riviana has demonstrated that chemical derivitives obtained from vegetable oils are also possible with rice oil.

Rice Milling Yields

20. The most important aspect of any processing technology is the yields that are obtained. Likewise with X-M processing, increased yields of edible rice is the key advantage of the technology. Increased yields, as shown by the experimental data of the original inventor, Mr. Truman B. Wayne, were what led to the commercialization and development of this technology. As you well know, commercial operations and laboratory experiments quite often differ in results. Therefore, it was determined to document these increased yields on commercial operations.

21. The X-M plant in Abbeville, Louisiana, was constructed adjacent to conventional facilities. Field rice cleaning and shelling operations

were performed in the old plant. The conventional bran removal facilities in the old plant were recently modernized and reinstalled to allow direct comparison of bran removal functions of both processing routes. The most difficult requirement of conducting this direct head-on comparison was that of being assured of the same raw material going through both processes. Since we were working with an agricultural raw material, it varies from lot to lot, or group to group and comparison of different groups would not be valid.

22. Equipment arrangements were therefore made to allow a given grouping of rice to be handled, cleaned, shelled and processed to brown rice feed material. This brown rice was then divided such that part of the grouping could be fed to the X-M processing equipment and part to the conventional processing equipment. This separation occurred with a limited holding period between either process such that as the brown rice was separated it was then fed to its respective processing routes. Scales and samplers were installed to measure total weight and sample for brokens on the brown rice feed to both conventional and X-M facilities. Similar scales and samplers were installed on the milled rice streams from both plants. By this, the exact weights fed to each plant and the weights of rice obtained from each plant and the brokens being fed and obtained from each milling operation were determined for a specific feed stream. Every effort was made to mill the rice to the same degree of milling and a number of checks were made to guarantee this situation. Over 17,000 metric tons of brown rice were milled in this manner and data collected on the test runs. This required operating for a period of several

months and controls were exercised to prevent distortion of data in either direction.

23. The 17,000 metric tons were broken into 26 separate milling lots and yield comparisons calculated for each of these. Included in these various lots were both long grain and medium grain U.S. rice varieties milled for both intermediate or partial bran removal products and for very well milled products. These carefully controlled tests conclusively show X-M milling to contribute higher whole kernel yields than that obtained from the conventional facilities. Also, the total milled rice yield from X-M milling was shown to be 1½% higher than that obtained from the conventional facilities. In addition, the head rice or whole kernel yield from X-M facilities is approximately 4½% higher than that obtained from equivalent conventional facilities. This average held constant for all four types of rice milling, although the individual lot results ranged from no yield increase to exceptionally high yield increases. This variation would be expected when working with an agricultural product on commercial operations.

24. We do, however, feel quite confident that these average numbers are obtainable in typical industrial rice processing ventures. Table I shows a summary of the average milling yields for these direct comparisons. Obviously, less defatted bran is produced than conventional bran in normal operations because of the extraction of oil and the non-contamination of bran with hulls and rice polish.

25. The production of dewaxed oil is based on extracting the bran and germ from an average level of 17-19% to the 1% level, plus the extraction of the rice kernel from its 0.7% level to approximately half of that.

TABLE I

COMPARATIVE YIELDS X-M AND CONVENTIONAL MILLING

Basis: Percent of Paddy Rice

Product	X-M Milling Yield	Conventional Milling Yield
Head rice (100%)	60.68	58.02
Broken grain	9.07	10.68
Conventional bran	-	9.69
Defatted bran (1% oil)	6.66	-
Degummed oil	1.48	-
Waste fatty solids	0.50	-
	78.39	78.39

Therefore, the rice [illegible] weight made up of rice extracted from the kernel, as opposed to only the bran and germ fats.

ECONOMICS

26. The economic profitability of the existing plant in Abbeville, Louisiana, has more than adequately demonstrated successful economics. To assess an economic projection for new X-M plants, it is required to determine the operating cost and product sales values for the specific business environment in which the plant is operating. Variables particularly significant include the cost per man hour for labor, availability and cost of hexane, market characteristics for the rice, bran, and oil products, and plant capacity. There are wide swings in the unit value of the variables from country to country. For example, in some countries defatted rice bran sells for premium prices, while in others it sells at discounted levels compared to conventional rice bran.

27. In order to develop more updated information for new plants, an outside engineering and construction company was commissioned to develop preliminary design and cost estimates for new plants. This activity was initiated late last year to provide accurate data for forecasting economic profitability. Within the scope of this study, the Abbeville plant was studied and design modifications were incorporated into a new plant design. Changes from the Abbeville design were restricted to proven processing unit operations, to avoid experimental operations in new plants. Detailed heat and material balances were made for the new design and combined with the experience

of operating the existing plant to calculate the projected operating expenses. Capital cost for construction and design of a total turn key plant were also estimated. These capital costs were based on direct equipment quotations.

20. A differential economic profile can now be calculated by combining the information obtained from the engineering study with the commercial comparative milling yields obtained from the Abbeville plant operation. Income, or earnings, is generated by sale of the three products obtained from processing brown rice, that is, polished rice, defatted rice bran and crude rice oil. Since X-M milling is only part of the total rice processing facility, the following economic discussion is based on a comparison between a modern, well run conventional rice milling facility and one with X-M rice milling facilities. Therefore, income credits are assigned only for changes in quantity and unit value of the products between the two processing routes. For example, income credits are assigned to X-M for the sale of the additional head rice obtained and for sale of the crude oil produced by X-M processing. A loss in income is assigned to the lower quantity of bran and broken rice kernels available for sale from X-M processing. Conventional bran removal operations are arbitrarily set at zero income; however, expenses are incurred. Therefore, in order to obtain the economic comparison, X-M processing is credited with saving the cost of conventional bran removal from the rice kernel, since operation of the conventional equipment is no longer required. Conventional bran removal operations have an estimated cost of $0.40 U.S. per metric ton of paddy rice.

29. For this general case study, typical U.S. bulk wholesale prices are assigned to the products, that is, $9.30 per hundred pounds head rice, $4.90 per hundred pounds broken rice grains, $1.60 per hundred pounds of both conventional or defatted rice bran, and $9.00 per hundred pounds for crude dewaxed rice oil. The net income generated by X-M processing by the change in products gained, or lost, by X-M rice milling in comparison to conventional milling is equal to $5.37 per metric ton of paddy rice.

30. Capital and operating expenses have been estimated for operations in the Far East based on the capacity of 90,000 metric tons per year of paddy rice. The estimated turn-key capital investment is $1.5 million. The annual operating expenses for labor, hexane, depreciation, supplies, utilities, etc., were estimated at $330,000 per year, which is equivalent to $3.66 per metric ton.

31. Table II shows a summary economic statement for the cash flow profitability for operating under the conditions assumed in this case. A payout of 4-5 years is forecast based on a yearly cash flow of [illegible].

TABLE II

SUMMARY ECONOMIC STATEMENT

Basis: 90,000 Metric Ton/Year Paddy Rice

Income				
Sale of additional products	($5.37)	(90,000)	=	$483,300
Savings from conventional operations	(.40)	(90,000)	=	36,000
Total				$519,300
Expense of Operation				330,000
				$189,000
Depreciation Add Back				$152,000
Yearly Cash Flow				$341,300
Payout of Investment				4.5 years

32. In summary, a technology for the solvent milling of rice has been developed and commercially proven. This technology offers the benefits of higher yields of milled rice with less kernel breakage, a defatted rice bran product stream which is storage-stable and high in protein, and the production of a low free fatty acid crude dewaxed rice bran oil stream. These benefits can be achieved in an economically viable venture when practiced as an industrial process in a suitable business environment.

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