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SUBSTANTIVE REPORT

X-M RICE TECHNOLOGY PROGRAM/AID PHASE I

ADAPTATION OF AN INTEGRATED RICE MILLING PROCESS AND DEVELOPMENT OF RESULTANT FOOD PRODUCT FOR USE IN SOUTHEAST ASIA, FED. FY'67-68

Riviana

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July 2, 1968

TO: Director
Nutrition and Child Feeding Service
Office of War on Hunger
Agency for International Development
Washington, D. C. 20523

Attention: Program Office, Contract No. AID/csd - 1583 (30 copies)

FROM: Lawrence Lynn for Riviana Foods Inc.

Subject: Final Substantive Report, Phase I

This report, covering the work on this program done in U.S. Fed. fiscal year 1967-68 is presented in accordance with the requirements of Contract No. AID/csd - 1583 with Riviana Foods Inc., P. O. Box 2636, Houston, Texas 77001, hereafter referred to as Riviana.

The general objectives of this project, Phase I of which was authorized June 30, 1967 were to (1) develop the applicability and adaptability of the general X-M rice milling technology, newly developed in the U.S. for upgrading of rough (paddy) rice and rice by-products, to countries of Southeast Asia; and (2) to provide knowledge which is required to make the technologically advanced know-how viable in a developing region, within the scope of the specific objectives, which were agreed upon. It was and is now anticipated that a new rice technology would offer major economic and nutritional advantages to countries in Southeast Asia.

Specific objectives included:

1) Developing several nutritious consumer food products based on projected availability of a source of X-M rice bran and oriented toward use of other inexpensive raw materials in Southeast Asia, including "bar good" products and a beverage. Nutritional and keeping qualities of these products acceptable to the people of Southeast Asia were to be considered.

2) Developing and/or adapting miscella refining techniques specific for rice oil produced by the new X-M technology to render in-line refining economically feasible in foreign X-M plants for the production of edible oil.

3) Determining the projected overall added value, in terms of rice milling yields, oil yields, and high protein bran properties, which would be derived from the X-M solvent extractive milling processing of selected foreign rice varieties.

The background for this project is summarized in the cover letter for the semi-annual progress report on csd-1583 dated January 29, 1968 and need not be repeated here. Aside from the question of providing a "cause celebre" for efficient rice milling with centralized storage and drying stations and higher milling yields especially of head rice, the currently largely wasted rice bran output problem remains a major need. With knowledge that protein malnutrition, the major problem in world food supply especially in the developing nations is increasing, estimates of world protein needs by 1970 are 85 MM tons/yr. At present rates of production increase, protein availability by 1970 will fall short by about 12% or 10 MM tons/yr. If human food uses for protein from rice bran can be convincingly demonstrated, about 4 MM tons/yr. of protein would become available for use against the increasing world shortage.

Thus, this is a major contribution which might be expanded from a dramatic improvement in the technology of rice and rice by-products.

The work completed in this project is presented in detail in the sub-project reports which follow, however, a synopsis of the highlights and an integral conclusion and recommendation can be given at this point:

1. (Sub-project 7.003)

It is very apparent, from this preliminary study, that Protex (defatted rice bran, germ and polish) presents a source for a rice protein concentrate which appears nutritionally exceptional (92% of the PER of milk protein based on animal feeding test), which offers promise of economic commercial feasibility, and which is functionally applicable to developing promising solid and beverage human food products. In this reference, note the spectrum of product probabilities, including food supplements, snacks, caramel-type candies, noodles and other pasta, and milk - like flavored beverages.

2. (Sub-project 7.004)

Miscella refining of rice oil, to alleviate the need for proximity to large, domestic type conventional oil refining facilities, appears technically and economically feasible. The indications are that no major added capital would be needed vs. conventional refining, that yield losses, hence cost of goods, for refined oil will be 3-5% lower than for conventional edible oil refining and that the in-use properties for the resulting cooking oil are slightly better, at least based upon pre-pilot samples, U.S. taste testing and objective measurements in this project.

3. (Sub-project 1.007)

This is the area in which only inconclusive results, unfortunately, are available.

During the first six months information on the almost 400 varieties in Thailand and the Philippines was gathered and collated, e.g. availability, chemical, physical and organoleptic data, etc. The group was screened to 20 key Thai varieties and 5 Filipino. Conventional milling test were started (McGill #3 type) while larger quantities of four varieties were ordered for shipment to Abbeville and Houston. Because of the time-dependent difficulties attendant on finding and ordering representative large samples, i.e. 4000 lbs, local assistance overseas from AID missions and other public and private section contacts, these samples were still in transit at the end of the project year. The small sample runs made in X-M on IR-8, inferred that it should work out in the same area as domestic Nato variety, i.e. without major changes in the X-M system.

Thus, the conclusion of the first six month report (Jan.29, 1968) must remain, that is while conventional milling results show head yields in the range 15-50 lb/bbl of paddy for some key varieties, X-M yields on generally analogous varieties typically run as high as 80-90 lb/bbl of paddy. This should leave much room for yield improvement, but whether this is due to better storage and drying, innate varietal characteristics, milling variables per se or other factors, must remain unclear at this time.

It is recommended that this new rice technology project be extended as follows, assuming priority and grant funds permit, during the period starting July, 1968:

1. Complete the yield and economic evaluation of the selected Thai and Filipino varieties now in transit and conduct at least small scale consumer acceptability tests vs. conventionally milled control samples.

2. Extend the work on the Protex (defatted rice bran, germ and polish) nutritions food products selected, i.e. from the group beverage, snack, confection, pasta, to include overseas consumer acceptability and development of a test marketing plan and budget.

3. Continue the work on rice oil miscella refining to the point of demonstrated overseas consumer acceptability test vs. indigenous vegetable oil consumer products.

4. Based on the results of 1, 2 and 3, complete the commercial development plan based on a thorough economic evaluation for the application of the X-M rice technology in one or more economical demonstration plant ventures in Southeast Asia.

FOR RIVIANA FOODS INC.

Lawrence Lynn, Vice President
Principal Investigator, AID csd - 1583

LL:ef

cc: Contracting Officer
Contract Services Division
Office of Procurement
Agency for International Development
Washington, D. C., 20523

Riviana Internal Report Distribution

PART I

DEVELOPMENT OF
PROTEIN-RICH FOODS BASED ON X-M RICE BRAN

Distribution
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Research & Development Dept.
Project 7.003 Report No. 2
DOS Contract AID/csd-1583
July 1, 1968

DEVELOPMENT OF PROTEIN-RICH FOODS BASED ON X-M RICE BRAN

Summary

Historically, rice bran has been considered a low value material of limited utility and with uses always outside of human food channels. X-M rice bran and properly defatted bran from conventional rice milling are both, however, clean, stable and edible for human beings. They carry 17-20% protein. If convincingly demonstrable applications can be found approximately four million metric tons of protein can become available for use against the world protein shortage.

X-M bran has been investigated as a raw material for inclusion into formulated food products to obtain the nutritional advantage of its protein content. Applications into consumer products were developed using X-M bran both directly and through its refinement first into a 70% rice protein concentrate. Prototypes demonstrating concepts of extrusions into noodle products with 25% protein at a cost of about 7 cents per pound of ingredients and snacks with 13-15% protein at a cost of 4-5 cents per pound of ingredients have been made. A "rice milk" beverage prototype with 3-4% protein and a confection base product with 13-14% protein have been formulated.

The various concepts, have been subjected to flavor evaluation, preliminary cost estimation, nutritional evaluation, stability studies, and formulation through pre-pilot development.

Flavor acceptance to American children, and to Thai and Chinese college students was found encouraging with isolated problems noted, in comparison to imported and domestically sold counterparts.

The products were all formulated using commercial ingredients and potentially scalable processing techniques.

The rice protein concentrate developed with 70% protein was demonstrated to be 92% as suitable as milk protein (casein) as a dietary protein by a Protein Efficiency Ratio based on animal feeding tests.

Conclusions

1. X-M rice bran can be incorporated into desirable human foods, styled as pasta, snacks, a beverage and confections.

2. Rice bran protein can be extracted and purified to a concentrate of 70% protein.

3. Rice bran protein has been found to be 92% as efficient as casein when evaluated as Protein Efficiency Ratio (PER) with rats.

4. Prototype products were generally acceptable or encouraging, in taste panels, to American children and Asian college students.

5. The prototype products have maintained adequate eating qualities up to six months without specialized packaging.

6. Cursory economic evaluation of the prototype foods does not eliminate their further consideration.

Recommendations

1. It is recommended that the apparent opportunity established for a new, edible and nutritious protein uncovered in the course of this work be followed up to establish its proper position among potential consumers.

2. Pilot scale process development for the production of the rice protein concentrate should be pursued paralleled by food applications research and product development.

3. The cursory economics developed should be refined based on additional data, as detailed in this report to establish marketability.

4. Consumer assessment on flavored prototypes should be studied further to establish local preferences for particular countries, e.g., Thailand and the Philippines.

5. The nutritional advantages of Protex should be related to dietary deficiencies of low protein diets and caloric intake through an expanded feeding program.

APPROVED

Lawrence Lynn

BY

John W. Hunnell

James I De Mont

Percie Lee Lamar III

Introduction

The Need For Protein

Protein malnutrition is the main nutritional problem in the underdeveloped countries. There have been several reports made on severe cases around the world. It is difficult to be specific about incipient cases, in part because of poor detection and reporting. Estimates are that the world's protein need by 1970 will total nearly 85 million tons. At current rates of production, protein availability by that time will fall short by about 12% or 10 million tons.

The need for additions to the world's protein supply has been broadly published. Notable presentations have been made by Milner (18), Altschul (3), and Abbott (1). The situation in summary is shown in Table 1. Variations in requirements are reflected in population differences in age, sex, body weight, work habits and most importantly in the quality of ingested protein. The low requirement for the United States is primarily a function of the high quality of combined protein available in the diet. It becomes apparent from this table that, on the whole, world protein supplies are not necessarily inadequate. The problems center around utilization. They appear generally as regional problems and are a function of a multiplicity of distribution and acceptance problems. Many of the people of the areas having a protein deficiency are those areas having rice as the mainstay in their diet. Therefore, the desirability of a locally acceptable and available protein source derived from rice becomes apparent.

As just one example, in Thailand dietary studies (4), (21) show that the food of the population especially in the rural areas, is high in carbohydrate, mainly composed of rice, and low in protein, fat, essential vitamins, and minerals. The consumption of meat, fish, eggs, and pulses is extremely low, and in many cases consumption of fresh fruit and vegetables is minimal. Yet these probably are the main sources of calcium and other minerals.

Fish protein constitutes the major source of animal protein. As sources of fats, lard is used in frying and coconut oil is used in preparing many dishes. Butter or oleomargarine are not used. Further complicating the Thai diet is that certain food taboos are known to exist for example, lactating women seem to eat little but rice and salt; eggs may not be taken by pregnant and lactating women, nor should they be given to small children.

Clinical studies show that endemic goiter, beri-beri and anemia are common. Several other signs of malnutrition have also been reported.

Similar studies show equivalent problems in the Philippines, Indonesia, and Latin America. The addition of a locally available source of protein would make a contribution to the nutrition of the general population.

Table I

WORLD PROTEIN SOURCES AND NEEDS

Dietary Protein Presently Consumed
Data is Given in Grams/Day

	Vegetable Protein				Animal Protein				Total	Average Daily Requirement in Grams/Day
	Grains	Starchy Roots	Oilseeds Nuts Pulses	Vegs. & Fruits	Meat & Pltry	Eggs	Fish	Milk Prdts		
North America	15.7	2.3	4.7	4.6	31.9	6.0	2.5	25.3	93	41
Australia & New Zealand	24.3	2.4	2.1	3.1	36.8	3.5	2.2	19.5	94	44
Western Europe	30.5	4.4	5.0	4.1	16.2	3.1	2.4	17.3	83	45
Eastern Europe & USSR	48.3	8.2	2.0	2.5	12.9	2.2	1.9	16.1	94	45
Latin America	26.5	2.7	10.7	2.8	13.8	1.2	1.5	7.4	67	45
Far East	32.2	1.8	12.0	1.7	3.0	0.4	2.2	2.2	56	46
Near East	48.5	0.7	9.5	3.6	4.6	0.5	1.1	7.4	76	45
Africa	32.2	7.1	9.0	1.7	5.8	0.4	1.3	3.5	61	41
World	33.4	3.2	9.0	2.3	8.8	1.2	2.3	7.7	68	44

Source: Food and Agricultural Organization, United Nations Food Balance Sheets, Rome Published 1960

Rice Bran As A Source of Protein

Rice bran has always been a potential source of valuable human food products because of its origin and content of high quality, digestible protein, but the potential has never materialized because of unresolved problems in milling, storage stability and most importantly the lack of creative applications research and food technology.

The primary use of rice bran in the United States is for poultry, cattle and pig feed. In Southeast Asia, however, it represents essentially a waste product with the limited exception of a small oil extraction industry. The protein potential is lost for human food outlets.

The significance of the possible addition of the protein from rice bran, polish and germ to the world protein supply by direct rather than by animal intermediates, needs little elaboration in view of the population growth vs the protein resource situation (18). The position of rice in the world food supply is preeminent, serving as the principal source of food energy for a greater number of people than any other single food item (20). Based on 1966 data (7) milled rice totaled 255 million metric tons, hence at 8% protein, this represents 20 million metric tons of protein vs 25 million from wheat and 20 million from corn. The protein lost in rice bran, germ and polish, essentially lost from a human nutrition viewpoint, totaled about 4 million metric tons.

X-M* rice bran, trademarked Protex*, is one of the concomittant products of the new X-M or solvent extraction milling process as applied to rice. The first commercial development of this process was announced in 1966 by Riviana Foods, Inc. in its newly completed unit at Abbeville, La. (13,15,16).

Traditionally, milling of the rice kernel to remove the bran layers from the endosperm has been done mechanically by abrasion and pressure. The X-M rice milling process (Fig. 1) is a departure from the traditional method of mechanical milling. The brown rice is first treated with rice oil to soften the bran layers and after a conditioning period, introduced into a rice oil-hexane miscella where the bran is gently removed by the rubbing action of a rotor and the working action of the miscella. Extraction of the oil from the bran and rice kernel is virtually instantaneous. The bran layers, rice polish and germ are then separated from the rice stream and the miscella, rinsed with dilute miscella, and desolventized in superheated hexane vapor. The resulting bran product is a dry, light tan colored, free-flowing powder with a clean, sweet, rather pleasing flavor.

* Trade mark of Food Engineering Internation, Inc., a subsidiary of Riviana Foods, Inc.

The general composition of Protex with comparative typical data for regular rice bran appears in Table 2 with vitamin and mineral composition in Table 3. The higher protein content, differing ash content and composition are most notable. Relative to bran from conventionally milled rice, Protex has good flavor stability, primarily due to the separation of the oil from the degrading lipases in the bran during milling. This quality coupled with its high protein content and bland flavor makes it suitable for the human food applications discussed in the course of this work.

Although a major improvement over conventional bran, as-is Protex with 0.5-2.5% residual lipids is still not completely storage stable. The naturally occurring lipolytic enzymes present in rice bran act to catalyze the hydrolysis of the lipids, as measured by free fatty acid (FFA) increase, which is rapid at typical atmospheric storage conditions. This breakdown is evident within a matter of hours or less for conventional bran (22), and a FFA content in the oil of 1.5-6% is common for so-called "freshly" milled rice bran. The literature (12) and unpublished data show the FFA content to double within 24 hours and quadruple within 48 hours. A 5 day storage period will severely damage both the oil and conventional bran for human food applications.

Storage and bran conditions, such as moisture content, relative humidity, and temperature also influence the rate of hydrolysis to some extent. Removal of the oil from the bran by solvent extraction stops the lipolytic oil deterioration, and removes some of the decomposition components from the bran which impair its palatability. This has been accomplished by conventional commercial extraction methods as well as extractive milling which largely separates the oil from the bran germ and polish during milling of the rice. While the remaining lipids are in insufficient quantity to cause major changes in the bran flavor quality from the viewpoint of some human food applications, other applications for defatted rice bran in foods require completely stopping hydrolysis. Such stabilization of rice bran is achieved by deactivation of the enzymes. Exposure to a steam atmosphere for 5-10 minutes at conditions to elevate the bran particle temperature to 200-220°F will deactivate the lipases. The enzyme activity can be measured by wet chemical colorimetric methods such as peroxidase activity determinations, which are highly indicative of lipase activity in bran. Untreated bran will show 6,000 - 10,000 units of peroxidase activity. After steam deactivation, the activity will be reduced to 0-100 units, depending on the specific deactivation conditions used, and even slight product quality degradation will have been stopped.

Table 2

COMPARISON OF PROTEX WITH CONVENTIONAL RICE BRAN

Properties	Protex (rice bran, germ and polish)	Commercial Mixes Rice Bran	Rice Bran Composite Literature Value*
Protein, %	17.0 - 21.0	11.0 - 13.0	10.6 - 14.0
Moisture, %	8.0 - 12.0	9.0 - 12.0	9.5 - 15.9
Fat, %	0.5 - 2.5	13.0 - 15.0	9.5 - 15.8
Crude Fiber, %	6.0 - 8.0	7.0 - 11.0	10.4 - 19.5
Ash, %	9.5 - 12.5	11.0 - 13.5	10.6 - 14.0

* Refs. (7, 10, 11)

Table 3

VITAMIN AND MINERAL CONTENT OF PROTEX

Thiamine	4.80 mg/lb
Riboflavin	2.60 mg/lb
Niacin	140 mg/lb
Pyroxidine	8.7 mg/lb
Iron	0.018 %
Calcium	1.43 %
Magnesium	0.22 %
Potassium	1.49 %
Phosphorus	1.50 %

The X-M Process

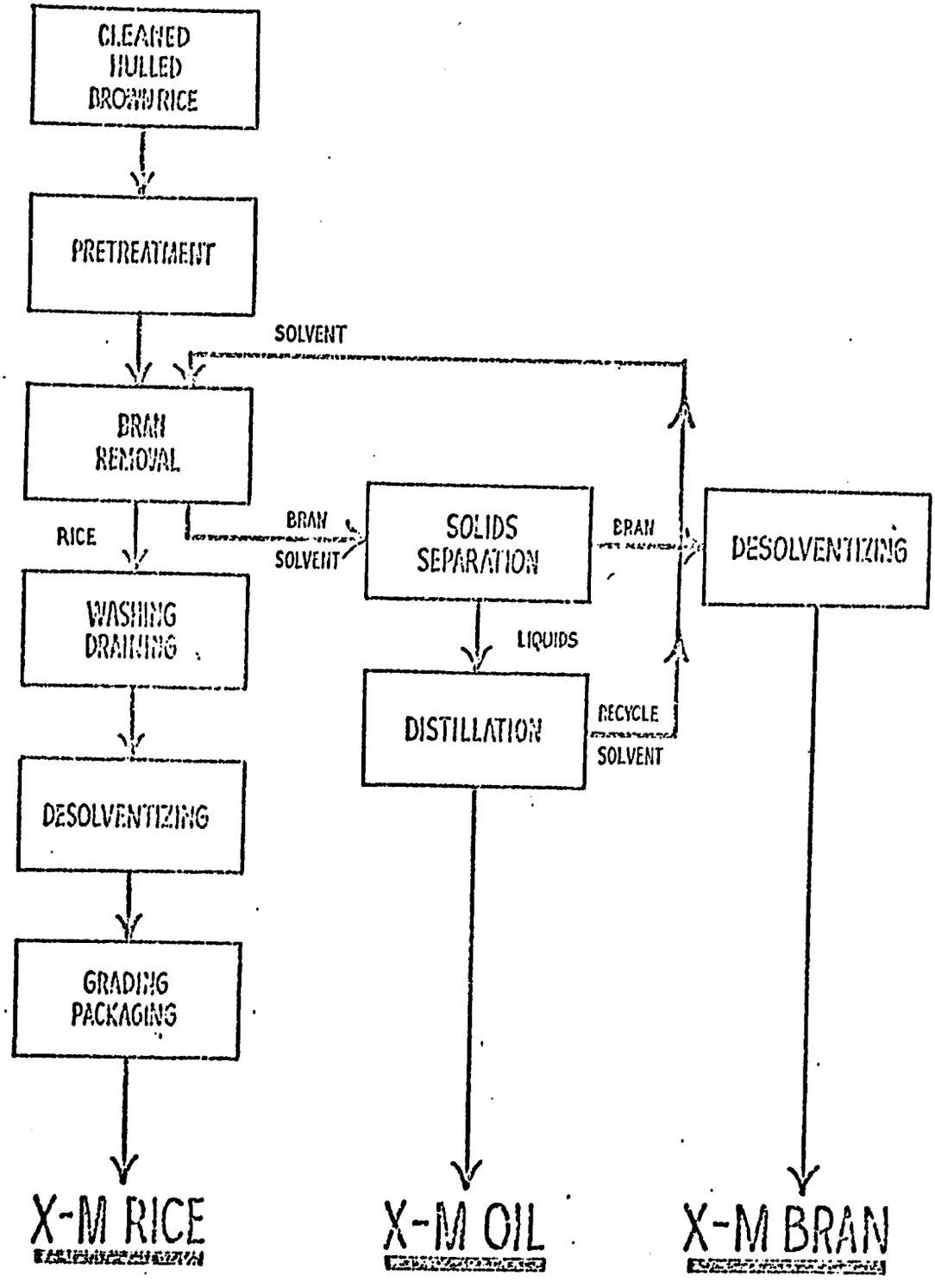


Fig. 1

Another approach to rice bran processing is to stabilize the bran oil by steam deactivation of the enzymes immediately after conventional milling from the rice kernel and preceding post-milling extraction. This also permits conventional extraction of the crude oil to accommodate to more convenient logistics and operating schedules. With post-milling extraction, however, even minutes of delay between milling and enzyme deactivation adversely affects ultimate oil refining economics and bran utility.

Direct Applications of Protex

Protex has the potential of being utilized directly in several applications. Two applications which have received good acceptance from tasters involved its incorporation into dough-processed snack type items and usage in coating formulations. In these applications:

1. Protex contributes to the protein level to raise the total protein content to 15% or more.

2. Protex contributes a bland, pleasant flavor.

3. Protex contributes to an attractive tan crust color.

4. Protex adds significant essential amino acids, minerals and vitamins to the product.

Product Formulation

Briefly described the following concepts are:

A. Use as a base for extruded snacks.

A combination of 1/3 Protex and 2/3 medium grain rice flour has been found to produce a structured food product when processed in a laboratory extruder at a temperature of 180°F. The dough for such an extrusion is formed by the addition of 1/3 water to 2/3 rice fractions by weight. It extrudes to a bland snack or breakfast cereal base that has found good acceptance by taste panels when either salted or sweetened. The ribbon of extruded dough may be immediately deep fat fried at 400°F for 30 seconds. Fig. 2, part B shows examples of the base material expanded in hot fat at these conditions, and dried extruded base suitable for coating with flavorings. Part C shows another form, not fried which was formulated with a meat flavoring for direct consumption.

The production and material balance for a typical small size snack operation is shown in flow diagram Fig. 3.

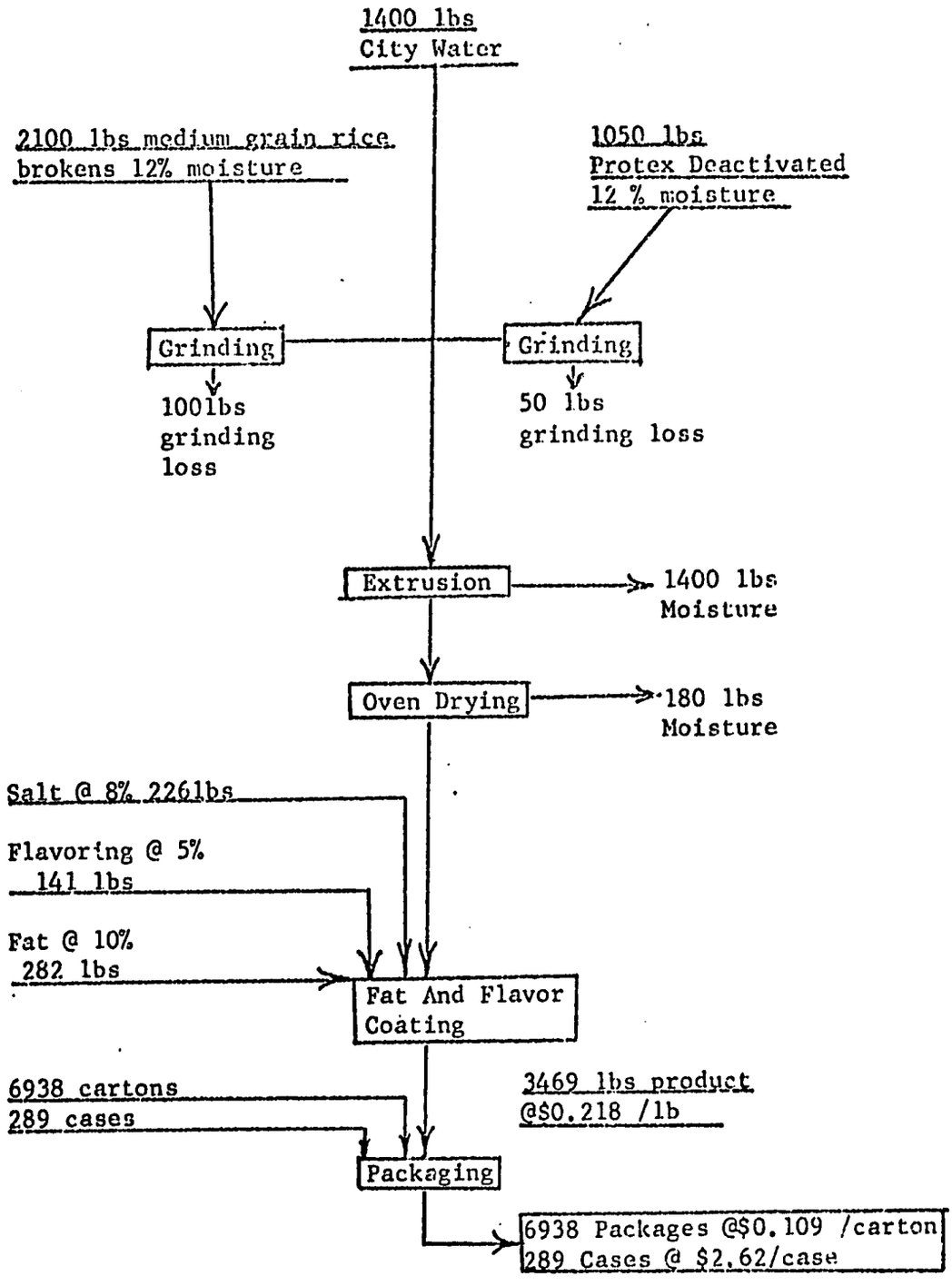
An extrusion line based on one of the smallest extruders available e.g around 300 lbs/hour of raw snack base, would yield approximately 400 lbs of flavor coated finished snack per hour. This 3,469 lbs of finished product per 8 hour day plant is estimated to require approximately $ 248,000 capital exclusive of land to produce a product at a cost of $10.9¢ per 8 ounce carton.

These figures are general estimates based on U.S. labor and plant costs. The detailed calculations supporting the costs reported are shown on the following pages.

Fig. 2
I - 14

Fig. 3

Puffed Snack - Material Balance 8 Hour Day Utilizing 400 pounds per hour Extrusion Line



PUFFED SNACK
PRODUCT COST SUMMARY

Capital Investment		
Purchased Equipment	$ 56,000	
Hopper, grinder, extruder, dryer, tumbler & packaging line.		
Installation	60,000	
Building & Services	70,000	
Auxiliary Facilities	10,000	
Physical Capital		$ 196,000
Engineering Fees	12,000	
Contractor Fees	20,000	
Contingency	20,000	
Sub Total		$ 52,000
Total Fixed Capital		$ 248,000
Direct Product Costs		
Raw materials, labor maintenance and utilities	$ 562/day	
Fixed Charges		
Tax, insurance, interest depreciation	160/day	
Plant Overhead	25/day	
Total Daily Cost	$ 757/day	

PRODUCTION RATE	COST OF GOODS
3469 lbs/day	$ 0.218/lb
6938 8oz package/day	$ 0.109/package
289 Cases of 24 pack/day	$ 2.62/case

PUFFED SNACK
DAILY PRODUCTION EXPENSES

Direct Product Costs		
Raw Materials	428.00	
Operating Labor	64.00	
Operating Supervision	24.00	
Maintenance	12.00	
Operating Supplies	4.00	
Utilities	30.00	
Sub Total		562.00
Fixed Charges		
Property Taxes, Insurance	20.00	
Depreciation (12 Years)	80.00	
Financing, Interest (6%)	60.00	
Sub Total		160.00
Plant Overhead		35.00
Total Product Cost		$ 757.00

B. Use in formulation of coatings and crusts for finger food or confections.

Finely ground Protex has been used in combination with wheat flour at a ratio of 1/3 Protex to 2/3 wheat flour to make a thin dough or cracker coating. The flour and Protex mixture is blended with sugar, shortening and leavening in a wet mixer. Such a dough is suitable for coating soft center confections when baked 9 minutes at 400°F. At this level of Protex, a highly acceptable product with good strength and texture is obtained. Higher levels of Protex give a dry mouthfeel to the coating. An example of this coated soft center is shown in Fig. 2, part A.

Product Evaluation

Several people from Thailand and one from Hong Kong were participants in a sensory evaluation study of these prototypes. Religious backgrounds included Hindu, Christian and none professed. The panelists predicted that some prejudice against rice bran products would probably exist among the uneducated masses because it is not customarily eaten. However, the volunteered thought was that the problem could be overcome through education and advertising. There was general agreement that people in Southeast Asia show small concern for inherent nutritional qualities of foods. Food is consumed strictly on the basis of flavor and appearance. Combinations of sweet, sour, spicy, hot and salty were best accepted as desirable and most palatable.

Snacks eaten range from the exotic in Hong Kong to simple desserts of naturally sweet foods in rural areas of Thailand. Banana and coconut are indigenous, but it was suggested the appeal of strawberry would be attractive to the natives. Sweet foods were classed as moderately to highly sweet and are commonly consumed.

1. Fat - puffed snack products (Fig. 2-B)

Opinion varied from liked slightly to liked quite a bit. All were acceptable. The general response was that these products would be liked only in certain areas of southeast Asia. Product improvement suggestions were the need for increased flavor levels either in the form of more salt or to make the product very sweet. The feeling of all the members of the panel was repeated for this concept that the people will eat only something they like regardless of any added nutritional value. They felt that some of the products would be salable but only with extensive advertisment to show the people it was good to eat yet different from other things they had they could make at home. This distinction was heavily emphasized.

PUFFED SNACK
DAILY RAW MATERIAL EXPENSES

	Amount	Unit/Cost	$ Daily Cost
Water	1400 lbs	30¢/1000 gal	0.05
Rice	2100 lbs	4.5¢/lb	94.50
Protex	1050 lbs	4.5¢/lb	47.25
Salt	226 lbs	2.5¢/lb	5.65
Flavoring	141 lbs	42¢/lb	59.22
Hydrogenated Rice Oil	282 lbs	18¢/lb	50.76
Cartons	6938 unit	1¢ each	69.38
Cases	289 units	35¢ each	101.15
		Total	$ 427.96/day

2. Bran coated soft center (plain and fruit flavored, Fig. 2-A).

   These products were very well liked. Fruit flavored products were preferred over the plain items (rice protein and caramelized sugar). It was felt that these products with modifications would be acceptable in most countries, e.g., a more moist and low flavored coating. The fruit fillings were made from open kettle dehydration of sweet purees combined with caramelized rice protein.

3. Hot air puffed snack

   This product was least liked. General comments were that it was too hard and needed salt and high flavor levels. This concept was not pursued further.

4. Non-puffed flavored extrusion product (Fig. 2-C)

   This product was liked in all aspects. It was accepted as a snack and consumed with a soft drink.

5. Sugar coated rice protein caramel. (Not pictured)

   General feeling is that this product would be liked in all the Southeast Asian countries, especially by children. This concept is a variation of No. 2. The addition of favorite fruit flavors was suggested. This product was liked quite a bit by all the panel except one who liked it only slightly commenting it needed more flavor. Other suggestions indicated sour-sweet or spicy flavors would be appropriate.

RICE PROTEIN CONCENTRATE

Raw Material

The raw material for the production of rice protein concentrate is defatted rice bran produced by the X-M process. This material processed and held in human food grade form is called Protex.

Production Technique

Methodology and techniques obtained through commercial and technical literature reviews combined with known technical information were adopted for usage in the treatment of Protex. Commercial enzyme preparations as listed in Table 4 were screened for activity in the solubilization process. Amylases proved particularly effective. Cellulases, proteases and pentosanases did not.

In order to enhance solubilization, during chemical treatment, Protex was subjected to various physical treatments such as freezing, thawing, heating and particle size reduction. Particle size reduction enhanced enzymatic action through increased surface area. Heating to the gelatinization point of rice starch greatly increased the rate of activity of commercial diastase preparations.

From 85-90% of the protein was found to be extractable with dilute alkali. Variable levels, from nil to a few percent of albumins, prolamines and globulins and some glutelin constitute the remainder. Up to 90% of the extractable fraction can be rapidly solubilized at pH 11.5. Solubilization increases from pH 10 to a maximum of pH 11.5; above pH 12, protein degradation and undesirable flavor effects became apparent. After residual solids removal, the soluble crude protein was recovered by precipitation at pH 5.0 as an off-white, bland paste with protein content of 70-75% dry wt. basis.

Protex is easily handled through the processing operations for the extraction of rice protein concentrate. However, the rice protein itself is more difficult to extract than most oilseed protein, in that good yields of protein concentrate are obtained only at a much higher pH than used in commercial soybean extraction. Protex also has a higher carbohydrate content than oilseed presscakes, and steps must be taken to decrease carbohydrate in preparing a concentrate. The basic elements for obtaining a rice protein concentrate involves aqueous alkaline extraction followed by acid precipitation. Sodium hydroxide and hydrochloric acid were found to be the most effective and economical agents for these steps. The process developed in this investigation is shown in Fig. 4.

Rice Protein Concentrates

The first approach to the development of a beverage concept was one in which the maximum possible quantity of X-M Rice Bran nutrients was to be solubilized or made more digestible and therefore more acceptable to the human digestive tract.

Production Technique

Methodology and techniques obtained through commercial and technical literature reviews combined with known technical information were adopted for usage in the treatment of Protex. Commercial enzyme preparations as listed in Table 4 were screened for activity in the solubilization process. Amylases proved particularly effective. Cellulases, proteases and pentosanases did not.

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Table 4

COMMERCIAL ENZYME PREPARATIONS INVESTIGATED

Enzyme	Class	Manufacturer
Cellulase 35	Cellulase	Rohm & Haas
Cellulase 4000	Cellulase	Miles
Cellulase 1000	Cellulase	Wallerstein
Cellzyme	Cellulase	Wallerstein
Meicellase	Cellulase	Meiji Seika Knisha Ltd.
Rhozyme H-39	Diastase	Rohm & Haas
Rhozyme P-11	Proteases	Rohm & Haas
Rhozymes	Diastase	Rohm & Haas
Rhozyme BP 150	Pentosanase	Rohm & Haas
Bacterial Amylase Concentrate	Diastase	Enzeco
Peptolac	Protease	Hansens
Premierzyme LA	Diastase	Premier
H T Proteolytic 200	Protease	Miles
Tansul	Protease	Baroid
WC-8	Protease	Wallerstein
Pepsin	Protease	Miles
Papain	Protease	Wallerstein
Pancreatin Powder	Diastase	Reheis
Rhozyme PL 600	Protease	Rohm & Haas
Rhozyme A-4	Protease	Rohm & Haas
Rhozyme 41	Protease	Rohm & Haas
Ficin	Protease	Miles
Protease (Miles)	Protease	Miles

Several factors were found to affect the final concentrate obtained. Varietal differences from the rice affect the color, flavor and consistency of the protein concentrate. The pH of extraction is among the more critical variables. The optimum pH consistent with yield and flavor requirements must be determined for each major variety and large volume commercial application. Holding time and temperature are also very important; temperatures high enough to cause gelatinization of the starch present have been found to inhibit protein extractability. Particle size should be controlled to obtain good extraction but clarification of "fines" causes counterbalancing difficulties. Acid treatment was found to extract considerable mineral material, but almost no protein. The best conversion obtained of X-M Rice Bran to the soluble state was through a combination of amylase and cellulase enzyme treatments followed by a series of alkaline protein extractions. Approximately 70-75% solubilization was achieved. The 30% residue was primarily fiber and ash.

Attempts at flavor and odor refinement of the enzymatic carbohydrate met with some success. Activated carbon treatment largely reduced the color and some odor toward blandness. A totally clarified extract still retained much of the objectionable bitter and grassy flavor present. Deactivation of lypolytic enzymes in the X-M Rice Bran improved the flavor of the concentrate.

Protein extraction in the 11.25 - 11.50 pH range appears to be optimum for best yield and best flavor. Boiling to gelatinize starches greatly reduced protein extractability, however, a sub-gelatinization heat treatment of 80°C followed by a liquefying diastase enzyme step, allowed efficient carbohydrate conversion and efficient protein extraction.

The temperature of extraction was found to have a marked effect on flavor. The combination of heat and alkali results in severe degradation of the protein with accompanying foul amine-like odors. No noticeable flavor benefit was achieved by boiling or steam stripping the alkaline extract. Calcium hydroxide did not provide as efficient extraction as NaOH. Added salts apparently do not act as peptizing agents with rice protein as they do with others as some fractions of rice protein are precipitated with 5% NaCl. The majority of the extracted rice protein is isoëlectrically precipitated with acid at pH 4.0-5.0. The minor constituent proteins are classically precipitated by other methods such as salt, heat and alcohol. The color of the rice protein concentrate varies from a deep olive green at pH 8.5 to a light tan at pH 4.0

The flavor of rice protein extract may be improved by re-suspension in water and re-centrifugation. A chalky mouthfeel is evident in the rice protein concentrate if it is not carefully clarified before precipitation. Fine carbohydrate particles entrapped in the protein floc during precipitation cause this chalky defect.

SEQUENTIAL STEPS IN THE PRODUCTION OF PROTEIN CONCENTRATE

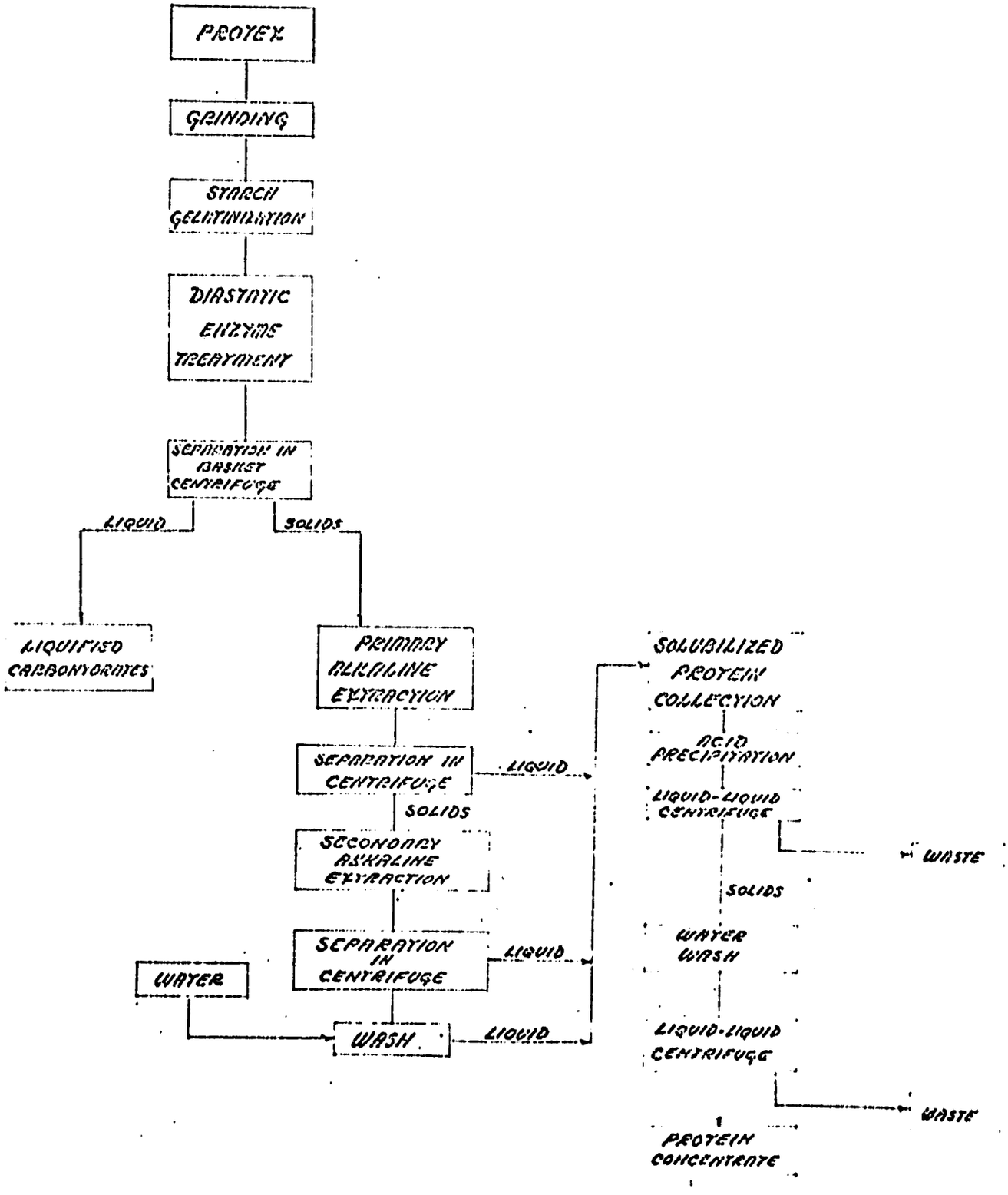


Fig. 4

Not only do suspended particles result in chalky mouthfeel, but the percentage of protein in the concentrate drops correspondingly due to the amount of impurities entrapped. A well clarified extract will contain in excess of 70% protein on a dry weight basis. Some of the fines and water soluble impurities may be removed by washing the X-M bran with water prior to extraction depending on the condition of the raw material. The holding time during extraction was not found to be critical. The quality of the concentrate will diminish with increased holding time, but the minimum time for extraction to take place appears to be two to four hours.

The concentrate may be retained as a gel form or may be dried on a surface such as a drum dryer or similar equipment. Such drying results in a tough, stable film or coating. These forms are shown in Fig. 5.

Nutrition

The rice protein concentrate has been subjected to analyses for utilization as demonstrated by the protein efficiency ratio (PER) technique and analysis of the amino acid spectrum.

It has been reported in the literature (19) that during maturation of the rice kernel, the albumin and globulin fractions first increase, then apparently decrease with the simultaneous increase in higher molecular weight and more complex protein fractions, glutelin and prolamin. This observation parallels that made for other cereals and gives rise to the conclusion that glutelin is a storage protein. It becomes the main protein constituent at maturity in rice to the extent of 85-90% of the total protein present. The comparable profile of amino acids from protein isolated from Protex vs protein recovered by Juliano (19) in the lab from mature brown rice appears in Table 5. The suitability of this protein as a nutrient is described by Bondi (5) as, along with oat protein, being superior to those of wheat and corn, but typical of cereals, being deficient in lysine and low in tryptophan.

For the determination of PER, thirty weanling rats per block were fed ad libitium diets where air dried rice bran protein concentrate, heat dried (mechanically processed) concentrate, and casein were used as sole protein sources at a level of 10%. The casein diet served as the reference standard.

After four weeks the PER values were calculated by:

$$\text{PER} = \frac{\text{Gain of test animals.}}{\text{Protein consumed}}$$

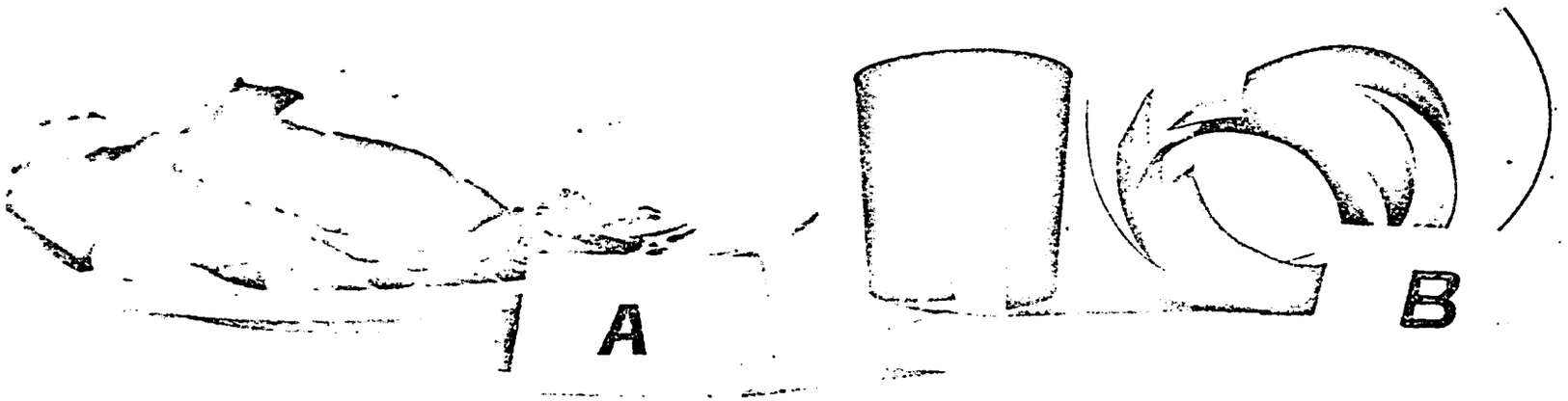


Fig. 5

The air dried protein concentrate showed a slightly improved PER value of 92% as compared to the heat dried product at 90.9%. Stated in absolute terms, the rice protein concentrate showed a PER value of 2.6 versus 2.85 for the casein control.

In feeding tests with intact Protex as a diet supplement, mature rats were fed standard laboratory chow ad lib. and were force-fed 0.5 g. of Protex every other day. Control rats had the same ration, with a supplement of conventionally produced rice bran. After 60 days the rats on the diet with Protex showed a weight gain of 19.5% while those on the control diet, 11.2%. Although this test was cursory, the results indicate beneficial nutritional properties in Protex. The protein efficiency ratio in this case using intact Protex was determined to be 1.7-1.9, compared to that of casein at 2.5.

It is important at this point to expand slightly on the essential amino acid content of the protein as shown in Fig. 6. The provisional pattern of essential amino acids in use by the Food and Agriculture Organization of the United Nations for human adults (11) is tryptophan, 1: threonine, 2: phenylalanine, 2: lysine, valine, isoleucine and sulphur containing acids (methionine and cystine), 2; and leucine 3.4. This means that for efficient protein use there should be a ratio of twice as much threonine and phenylalanine as tryptophan, and three times as much lysine and the others - except leucine, of which there should be 3.4 times. Fig. 6 graphically illustrates that the ratio of essential amino acids in Protex protein is of good quality and is above the FAO requirements for these amino acids. Thus, the impact of this versatile "new" food ingredient, can be a significant expansion in food supply without a corresponding increase in food production.

As seen in Table 6, compared with most other cereal protein the rice protein in bran is of high quality and compares favorably with the protein of oilseeds and legumes. The rice data show some apparent conflict with other amino acid assays (Table 5), explainable however based on variety and crop year differences. Rice bran protein contains three times as much of the limiting amino acid of soybeans, methionine (2). Rice protein contains no known anti-nutritional factor such as the trypsin inhibitor of soybeans and may be classified as a partially incomplete protein (10). Slight additions of milk protein or fish protein concentrate would make rice protein nutritionally excellent.

Product Costing

The cost of producing the rice protein concentrate for a small plant to produce 3-4 MM lbs/year from Protex was roughly estimated using two approaches, empirical formula from conventional chemical cost engineering techniques and by equipment cost factoring. These estimates were based on limited data and many assumptions; however, they should serve to indicate a general "order of magnitude: cost picture. On the basis of one ton of Protex per hour, the formula estimate was higher by approximately $25,000 per year. Raw material calculations were based

Table 5

AMINO ACID PROFILE ON PROTEIN FROM PROTEX

Amino Acid	% of Protex* Protein	% of Mature** Brown Rice Protein
Aspartic Acid	9.12	9.23
Threonine	3.84	3.63
Serine	4.60	5.60
Glutamic Acid	15.70	23.00
Proline	4.47	5.05
Glycine	6.24	4.74
Alanine	6.80	5.41
Valine	6.00	5.14
Half-Cystine	0.66	0.51
Methionine	1.95	1.62
Isoleucine	3.60	3.90
Leucine	7.60	8.14
Tyrosine	3.18	5.52
Phenylalanine	4.53	5.62
Ammonia	3.27	2.29
Lysine	4.11	3.07
Histidine	3.30	2.52
Arginine	9.63	9.46
Tryptophan	1.30	1.57

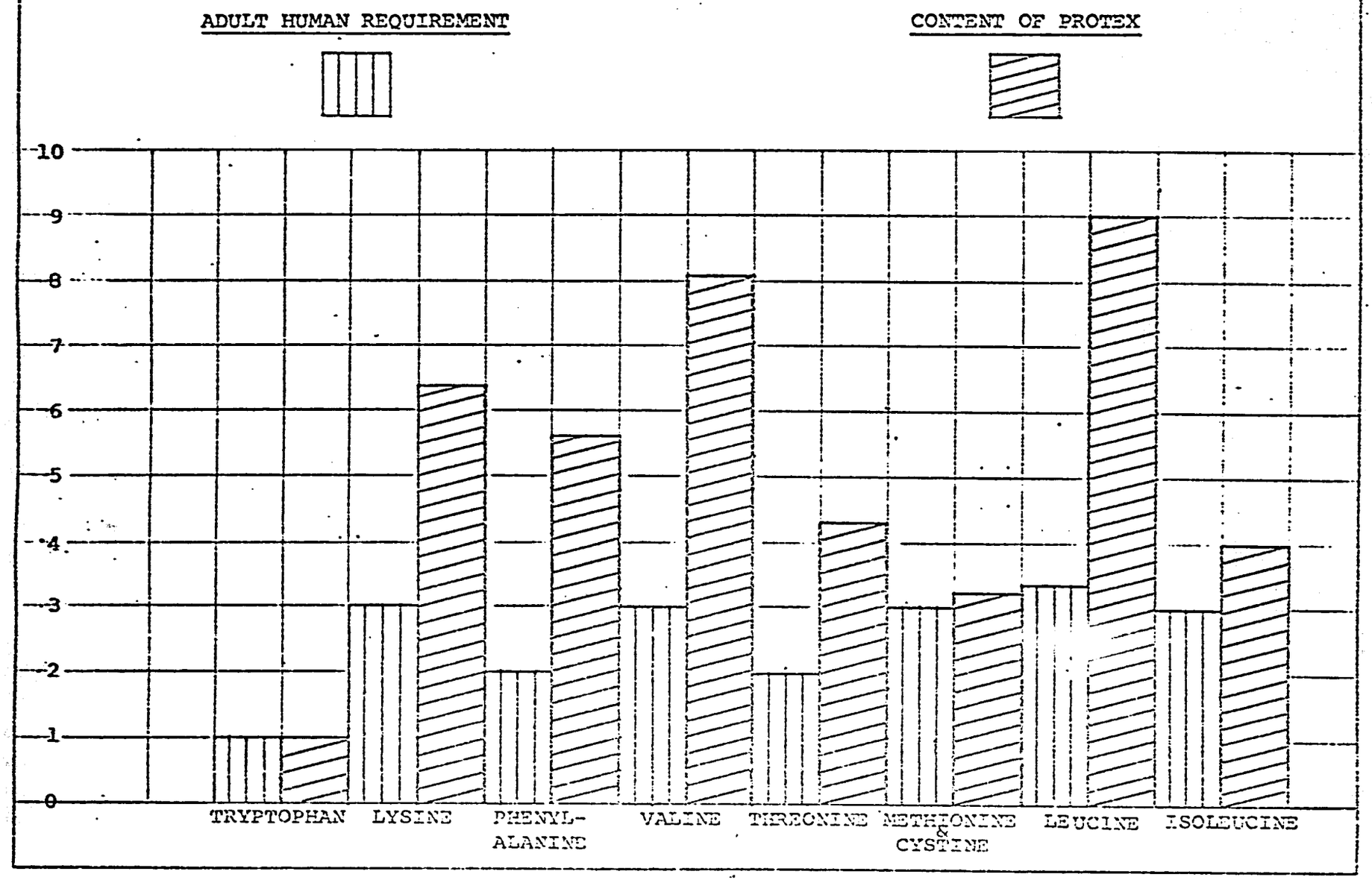
* Analysis from Riviana Laboratories and Univ. of Missouri, Dept. of Agriculture

** Ref. 23

Figure 6

COMPARISON OF ESSENTIAL AMINO ACID RATIOS OF PROTEX WITH ADULT HUMAN REQUIREMENTS*

*BASED UPON THE PROVISIONAL PATTERN IN USE BY THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS



on previously obtained laboratory and pilot plant data. Crude 70% protein (dry weight basis) concentrate was estimated to cost 13.2¢/lb from these calculations. The material balance for the process involving alkaline extraction of protein followed by acid precipitation and centrifugal recovery is given in Fig. 7.

The following are the elements of the cost analysis:

I Capital Cost

A. Equipment Factor Method

Equipment		
Grinder	$ 5,000	
Extractor	22,000	
Centrifuge	24,000	
Precipitor	17,000	
Centrifuge	24,000	
	92,000	
	X 4	(Ratio factor to estimate facility capital requirements)
Subtotal	368,000	
	20,000	Waste Disposal
	30,000	Storage
	40,000	Engineering & Design Cost
	458,000	
	69,000	(Contingency @ 15%) *
Total Capital	$ 527,000	

* Undetermined processing for intermediate refining steps such as activated charcoal decolorizing.

B. Processing Steps & Capacity Method

Empirical procedures calculated at $ 550,000 capital investment requirement.

II Operating Costs - Yearly

Raw Material	$ 266,000
Direct Labor	62,000
Amortization	86,000
Utilities	5,000
Maintenance	33,000
	$ 452,000/year

III Cost of Goods

At production rate of 2.4 MM lbs/year (100% protein basis) =

18.8¢/lb protein

13.2¢/lb 70% protein

Table 6

COMPARISON OF ESSENTIAL AMINO ACIDS IN RICE PROTEIN WITH THAT FROM SOY, WHEAT AND CORN

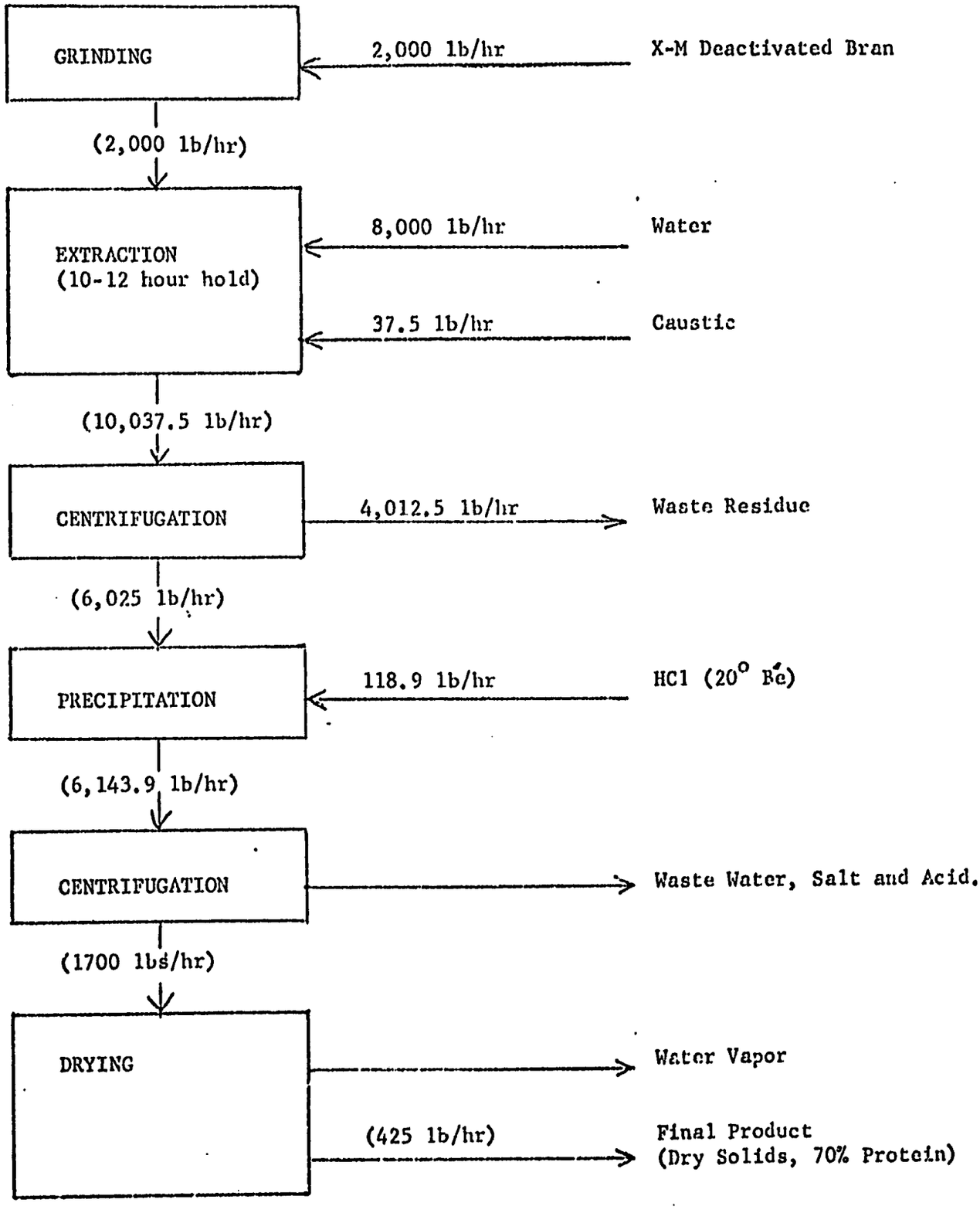
	Rice Bran	Soy Bean	Wheat	Corn
Arginine	9.5%	7.71%	4.4%	4.8%
Histidine	3.1	2.63	1.7	2.5
Isoleucine	5.0	5.59	4.7	6.4
Leucine	7.3	8.14	6.3	15.0
Lysine	5.9	6.06	3.1	2.3
Methionine	3.6	1.33	0.68	3.1
Phenylalanine	4.6	5.90	3.8	5.0
Threonine	3.9	3.70	2.8	3.7
Valine	6.4	6.58	4.0	5.3
Tryptophan	3.8	1.04	1.4	0.6
Tyrosine	5.2	3.36	3.7	6.0

Amino acid values are given as percent of protein.

Ref. 14

Fig. 7

MATERIAL BALANCE FOR RICE PROTEIN CONCENTRATE



MATERIAL BALANCE

Raw Material Usage

Material	Estimated Unit Cost	Quantity	Value
Bran	1.5 ¢	16×10^6 lb	24,000
NaOH	3 ¢	0.3×10^6 lb	9,000
Water	.004¢	64×10^6 lb	2,500
HCl	4.9 ¢	0.3×10^6 lb	14,500
		80.6×10^6 lb	$ 266,000

Production

Material	Quantity
Extract Centrifuge Overflow Waste	45.1×10^6 lb
Product Centrifuge Underflow Waste	32.1×10^6 lb
Product	2.4×10^6 lb
	80.6×10^6 lb
	3.4 MM lbs/year dry 70% protein
	2.4 MM lbs/year pure protein

Products Formulated from Rice Protein Concentrate

The development of the rice protein concentrate previously described gives a new ingredient material, high in protein at 70% (dry weight) to act as the base for the formulation of a variety of foods.

Three distinctly different concepts were developed to demonstrate the versatility of the base. Each may be formulated to have a higher protein content than its presently available counterpart and each has been found to have good acceptance in taste panel studies. All three can utilize the rice protein concentrate both in the hydrated or gel form or from the dehydrated powder form. In the following discussion each product was made from the gel form as a starting point.

A. Beverage

Rice protein concentrate was formulated into a "rice-milk" drink. Such "rice milks" have been formulated to contain as much as 6% protein. A 3-4% protein drink is more consistent with similar products considered for a cow's milk substitute. The inclusion of 3-4% X-M rice oil or other suitable fat and an emulsifier gives a stable oil-water emulsion with the rice protein base. The base used is a light tan colored and virtually odor and flavor free gel. It is well suited for flavoring and coloring with fruit and other flavors. The composition of such a rice milk product compared to cow's milk is given in Table 7.

Rice protein concentrate and rice milk made from it are both stable at retort and high temperature-short-time sterilization conditions. However, the choice and handling of oil or fat for use in sterilizing rice milk require careful consideration as oxidation and off flavors during sterilization are usually traced to this component. Fig. 8 shows a photograph of a rice protein concentrate beverage prepared in this manner.

The production of a "rice milk" product would follow a flow diagram similar to that shown in Fig. 9.

Assuming a bottling installation utilizing a 120 units/minute filling machine, a plant capable of manufacturing 11,800 lbs of rice milk per day is roughly estimated to require a $177,000 capita investment, exclusive of land, and produce the product at a cost of approximately 4.1 cents per bottle when the rice protein concentrat raw material is supplied at 13.2¢/lb.

The cost data summary below shows a partial breakdown of the manufacturing costs. Other detailed data follows.

Table 7

COMPOSITION OF MILK-LIKE BEVERAGE FROM RICE PROTEIN CONCENTRATE VS COW'S MILK

Component	Rice Milk	Cows Milk*
Protein, % wt.	3.60	3.42
Fat, % wt.	4.00	3.67
Mineral, % wt.	0.70	0.73
Carbohydrate, % wt.	9.06	8.77
Water, % wt.	81.85	87.30
Total Solids % wt.	18.15	12.70

* Ref. 17

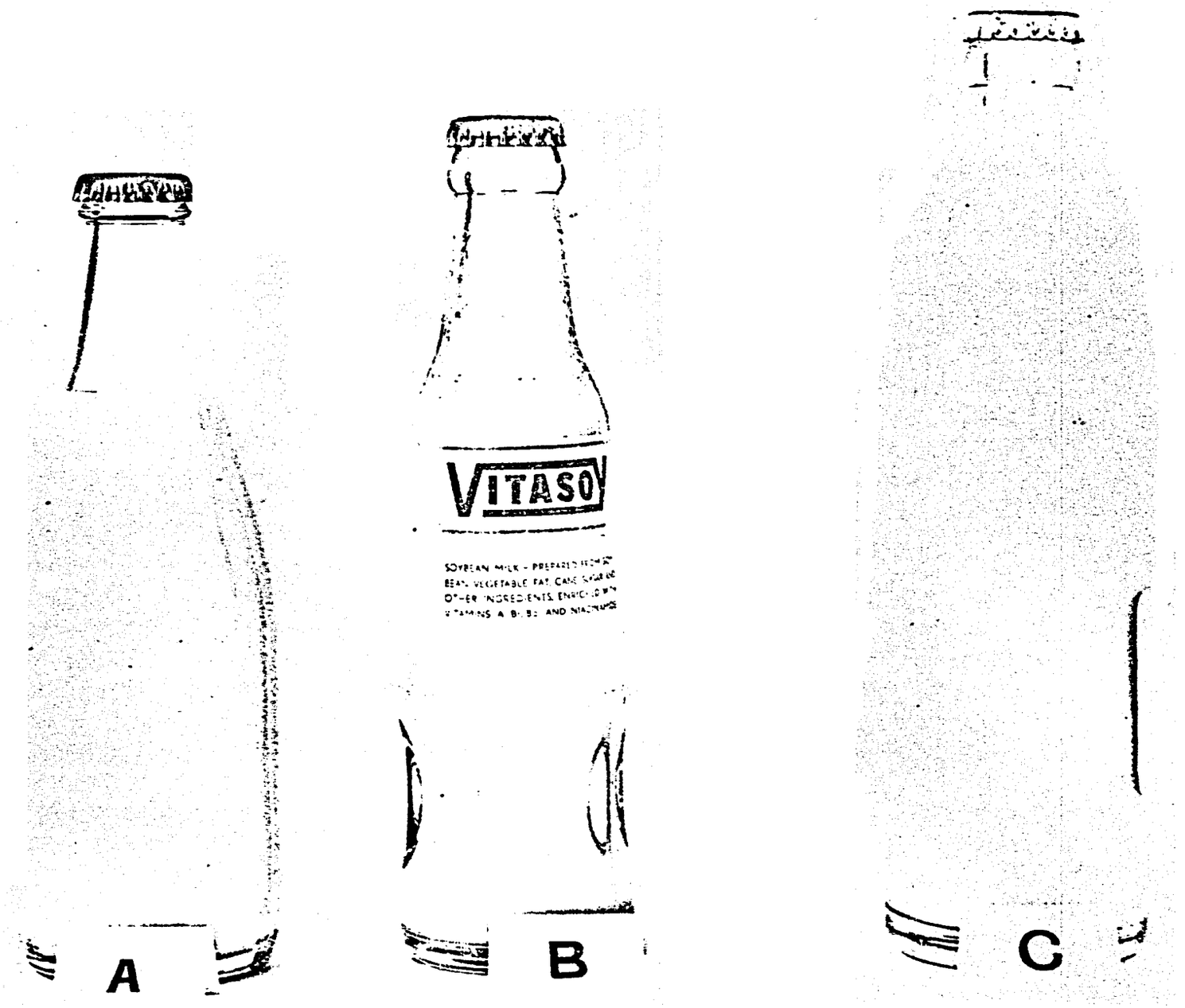
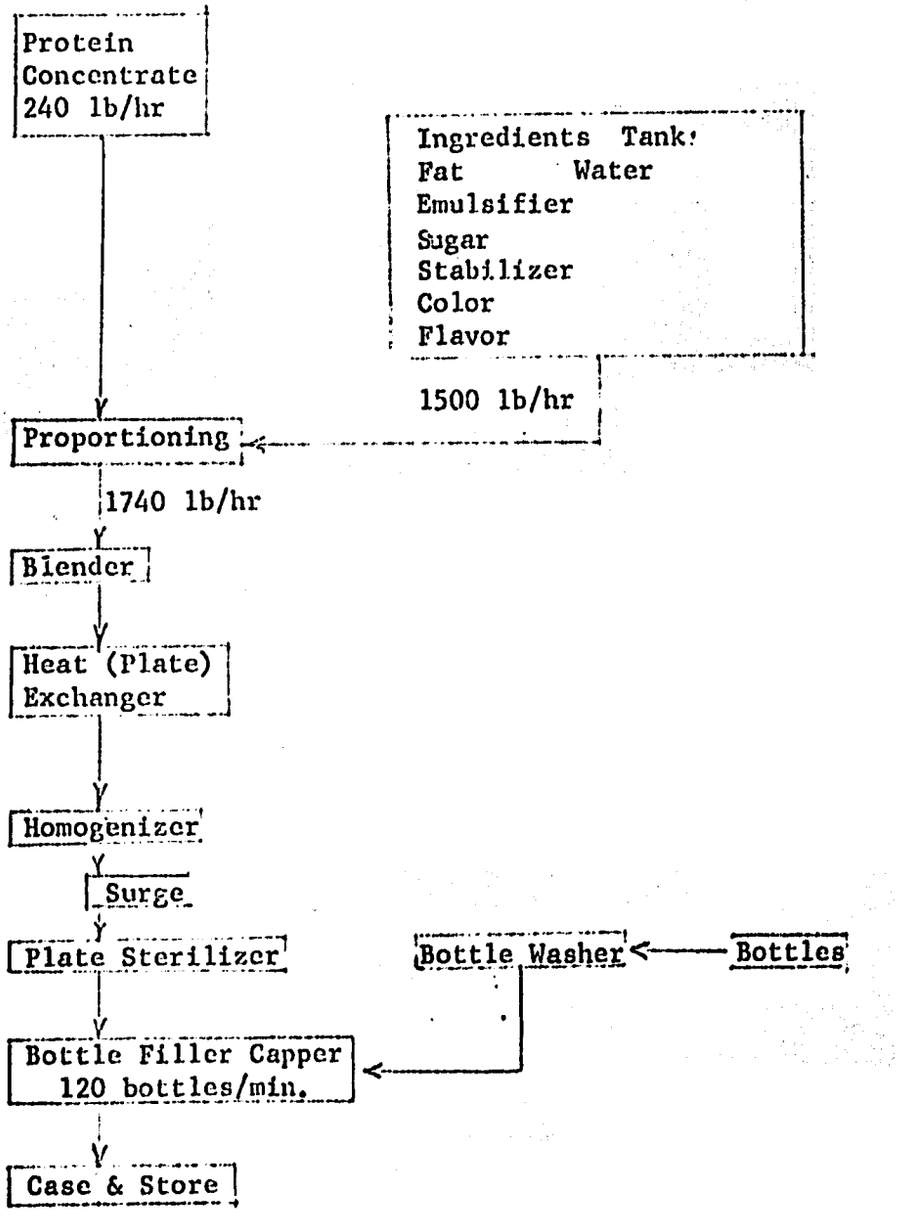


Fig. 8

Fig. 9

Rice Milk Flow Sheet
200 gal/hour



Rice Milk
Cost Summary

Capital Cost

Equipment	$25,000
Installation	50,000
Building & Services	70,000
Auxiliary Facilities	5,000
Fees & Contingency	26,000
Product Capital Cost	177,000

Direct Product Cost	1,129.43/day
Fixed Charges	114.00/day
Plant Overhead	35.00/day
Daily Cost	1,278.43

Cost per pound	10.08¢(11,800 lb /day)
Cost per 6oz bottle	4.1 ¢

RICE MILK
DAILY MANUFACTURING COSTS

Direct Product Costs		
Raw Materials	1002.43	
Operating Labor	54.00	
Maintenance	24.00	
Operating Supervision	24.00	
Operating Supplies	5.00	
Utilities	20.00	
Sub Total		1129.43
Fixed Charges		
Property taxes, Insurance	12.00	
Depreciation (12 years)	60.00	
Financing, Interest (6%)	42.00	
Sub Total		114.00
Plant Overhead		35.00
Total Product Cost		$1,278.43

RICE MILK
DAILY RAW MATERIAL EXPENSES

Ingredients	Unit Cost $	Quantity	Daily Cost
Water	4X10-5/lb	8,490 lb	0.34
Rice Protein Concentrate	0.043 /lb	1,620 lb	69.66
Oil	0.15 /lb	472 lb	70.80
Sugar	0.10 /lb	1,180 lb	118.00
Flavor	7.00 /lb	15.35 lb	107.45
Color	9.79 /lb	3.89 lb	37.93
Emulsifier	0.50 /lb	11.8 lb	5.90
Stabilizer	2.00 /lb	7.9 lb	15.80
Sub Total		11,800 lb	425.43
Bottles	0.015 each	31,426	472.00
Carton	0.02 each	525	105.00
		Total $	1,002.43
		Material Cost 6oz Bottle	3.18¢

Rice Milk Formula Cost

100 Pounds Rice Milk

Ingredients	Quantity Pounds	Cost Per Pound $	Total $
Water	71.950	0.00004	0.002
R.P C.(wet 30% ts)	13.720	0.043	0.590
Oil	4.000	0.15	0.600
Sugar	10.000	0.10	1.000
Flavor	0.130	7.00	0.910
Color	0.033	9.75	0.320
Emulsifier	0.100	0.50	0.050
Stabilizer	0.067	2.00	0.134
		$	3.606 /cwt.

During the past few years products similar to this "rice milk" have been successfully sold by companies such as Lo's Hong Kong Soya Bean Products Co. Lo's product, Vitasoy, sells at the rate of about 3 million cases per year at a cost of about 3.5¢ (U.S.) for a 7 oz. bottle, and outsells both CocaCola and Pepsi-Cola in Hong Kong.

Green Spot, another Hong Kong company, is marketing soy milk in Thailand under the trade name of Vitamilk. They have succeeded, even among uneducated people through lucid advertising.

Products such as these are consumed hot or cold. Most taste something like lima beans to the American palate. Fig 8 shows the prototype rice milk as bottle A. Bottles B and C are commercial products from Hong Kong and Taiwan respectively.

The rice milk prototype like the other products can be flavored many ways. In taste panels using Chinese and Thai students plain rice milk with a natural beany taste was equally acceptable with Vitasoy in flavor. The respondents commented negatively on cow's milk and the protein beverages on their filmy, oily mouthfeel. The ideal beverage according to the Thai students should leave a clean feeling in the mouth and throat after consumption.

In an another evaluation study with the rice milk two kindergarten classes of American children participated in a preference test between the strawberry-flavored rice bran milk and Pillsbury's Moo Juice product mixed with milk. The drinks were served in paper cups marked with red and blue tape.

The children were asked to taste each sample and indicate on index cards, also marked with red and blue tape, their preference. These instructions were easily understood by most of the children, but one or two marked the cards without tasting or marked both colors. Even so, those observing feel that this method of determining preference was successful.

A total of 33 children tasted both beverages. Although the Moo Juice was preferred by 28 of the children, it is important to note that very few of the children demonstrated strong negative feelings toward the rice milk. Some commented that they did not like its color which was darker and tending towards a rasberry color rather than strawberry. Several others stated that the Moo Juice was more like a milk shake and like something they had had before. Two described the bran product as tasting like medicine and another like alcohol.

Despite the very obvious differences in the two beverages, the children did not react negatively to the bran milk. Even though the Moo Juice was significantly preferred, it is believed that this preference is reasonable because of probable association and familiarity with commercial milk drinks, such as Moo Juice and Great Shakes.

B. Pasta Products

Nearly all cultures, including many quite primitive ones have a thin, dried dough item in the listing of foods commonly eaten. Noodle products based on rice and/or wheat flours are made and consumed in Southeast Asia. Most often they are only extruded rice flour made up with water and sold as a rice stick or Maifun which is used in entrees, soups or deep fried and used with chicken or vegetable salads. The protein content of Maifun is typical of rice, 7-9%.

Rice protein concentrate may be used in combination, for example, with rice flour from parboiled rice to make a noodle or shaped pasta with a protein content of 20-25% (dry weight). This is based on the combination of one part of dry rice protein concentrate with 70% protein, to three parts of the rice flour. The flour is combined with water in the ratio of 2.15 - 1.0 prior to extrusion. A standard macaroni extruder is used in preparation of the noodle product. Such a product, as shown in Fig. 10B, has a light brown color and a bland flavor when boiled in salted water for 5 minutes. The cooking quality of the rice protein/rice flour noodle may be improved with the addition of agents such as 0.2% carrageenan, 2-4% egg yolk or other additives.

Noodles such as those described are conveniently manufactured on conventional extrusion and pasta equipment. Shape and cooking quality are controlled by several variables including moisture in the formula, preblending and/or precooking the ingredients, extrusion time, temperature and pressure, drying conditions and functional additives. The great latitude in processing allows the tailoring of the products to specific desirable characteristics.

Taste panels conducted in the test kitchens on boiled pasta types gave excellent ratings to the products. They were found to be well suited to combination with sauces.

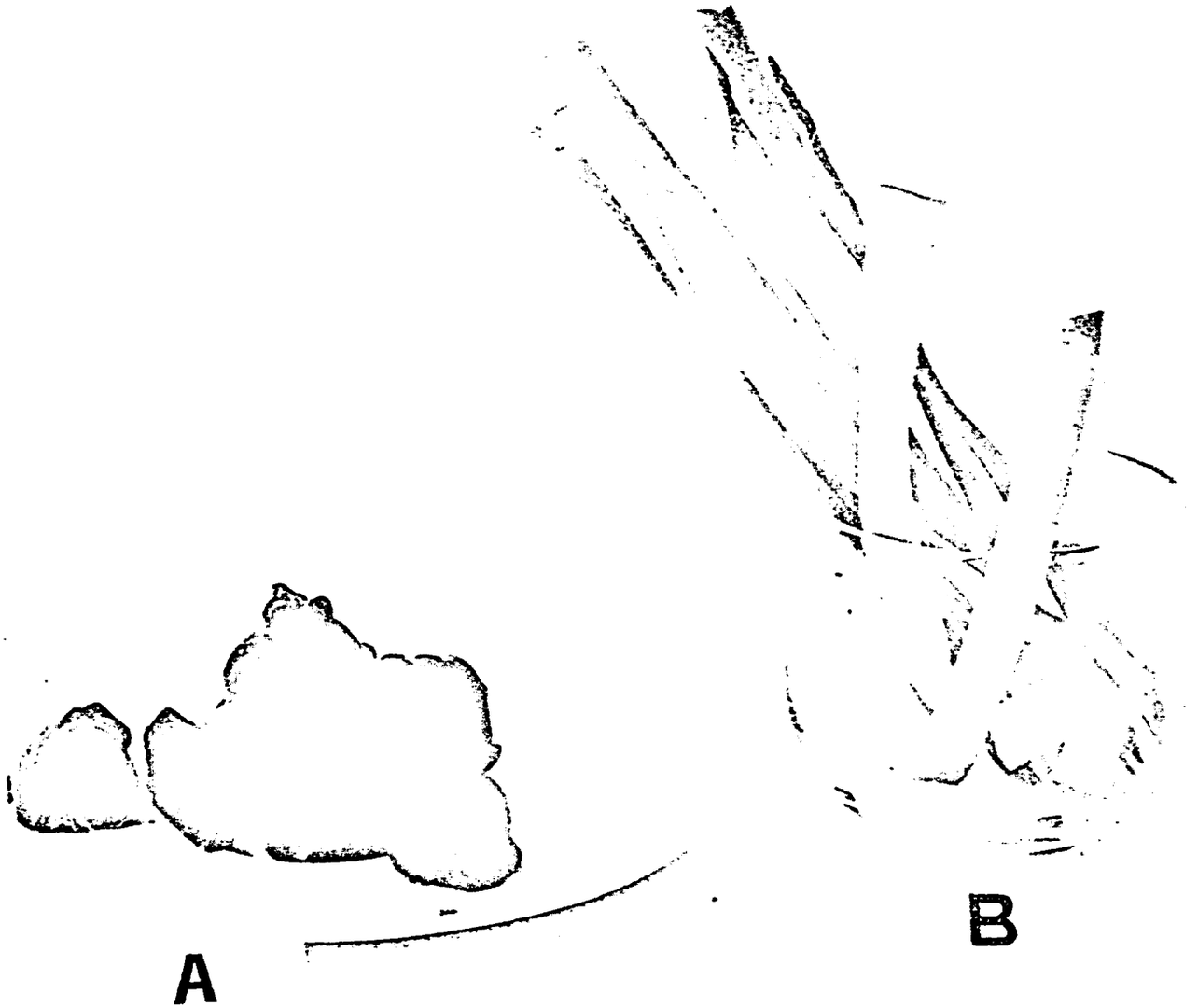


Fig. 10 I - 44

C-Confection Products

Another broadly accepted food concept amenable to protein fortification is the area of confections.

The rice milk previously described has been used as a substitute for cow's milk in a standard caramel formula. Rice oil with an available commercial heat stable butter flavor was used for fat in substitute for a margarine or butter. Conventional candy processing at 240°F yields an attractive caramel as shown in Fig. 10A with a flavor equivalent to one made with cow's milk and butter. Caramel of this type has been coated in several forms to give highly acceptable products. Of the coatings used chocolate and hard sugar were best received. The Protex crust type coating mentioned earlier has also been effective for confections.

When the gel form is used in total replacement of water, a caramel carrying 13-14% protein is obtained. The high protein caramel has a slightly stronger flavor than the regular rice milk caramel but was readily acceptable to most taste panel members.

This material was found to be compatible with fruit flavor, e.g., banana, coconut, lemon-lime, etc. When coated with chocolate, hard sugar or Protex crust type coatings, it made an appealing nutritious confection.

The chocolate-covered Rice Protein caramel was also evaluated monadically by the 33 child kindergarten panel. The majority of the children liked the candy, said it tasted like Milky Way, or that they would buy it. Two, however, would not eat their samples and one said he did not like it even though he had already eaten it. Such testing demonstrates that the bran is acceptable as candy to American children.

The Thai and Chinese college student panel returned the opinion that these products would be liked in all the Southeast Asian countries, especially by children. The addition of various fruit flavors was suggested. This product was liked quite a bit by all the panel except one who liked it slightly saying he felt it needed more flavor. Suggestions volunteered indicated sour-sweet spicy flavor would be appropriate.

PART II

RIVIANA FOODS, INC.
Houston, Texas

DEVELOPMENT OF RICE OIL MISCELLA REFINING TECHNOLOGY

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Research & Development Dept.
Project 7.004 Report No. 2
DOS Contract AID/csd-1583
July 1, 1968

DEVELOPMENT OF RICE OIL MISCELLA REFINING TECHNOLOGY

Summary

A process has been developed for the refining of crude dewaxed rice oil in the miscella state such as found within the X-M process for rice milling. The trade claims for miscella refining of vegetable oils for obtaining lower refining losses and better product color than by conventional refining, were validated for rice oil. This development was achieved through study of previously available information, laboratory investigations and pre-pilot unit operations. An economic analysis has been made based on the data generated, additional assumptions, and conventional estimating procedures. This analysis indicates the process to be both technically feasible and potentially able to provide an additional economic advantage to the use of the X-M process or a similar process by adding a useful and nutritional product to the food supply of the countries of Southeast Asia, or other areas.

The project is complete to the point of (1) large sample production for acceptance testing in a specific use area to evaluate product acceptability and saleability and (2) full pilot scale operation for determination of optimum operating conditions to generate data needed for commercial design engineering.

Conclusions

1. The published literature on miscella refining of crude cottonseed oils shows the process to be a commercially proven competitive process with lower refining losses and lighter product color claims than conventional refining.

2. The major concepts of miscella refining of cottonseed and soybean oils are applicable to the refining of crude X-M dewaxed rice oil.

3. X-M dewaxed crude rice oil produced from U.S. Gulf Coast rice varieties can be miscella refined and further processed to a premium quality finished cooking oil.

4. Analytical data reported in the literature for world wide rice varieties do not indicate gross differences in the chemical nature of their respective rice oils. Therefore, processing of foreign rice oil stocks does not imply any obvious or drastic changes or requirements to the miscella refining process from variety to variety.

5. The "order of magnitude" cost estimates for miscella refining appear to be in an acceptable range for a six million pound per year product plant based, however, on an operation in the United States.

6. Miscella refining of X-M crude rice oil results in significantly lower losses than those experienced with conventional refining. A 3.8% FFA crude rice oil showed a 6.2% refining loss by miscella refining and a similar 4% FFA crude rice oil showed an 11.1% refining loss by conventional refining.

7. Manufacturing costs of miscella refining is estimated at 3-6% less than conventional refining for dewaxed oils having 3-5% FFA content.

8. On-site miscella refining facilities could be a valuable adjunct to X-M units in such areas as Thailand and the Philippines, because they would provide the mechanism to refine X-M crude rice oil to a potentially valuable nutritional product without the toll refining fees, logistics and transportation and storage problems associated with large scale contract conventional oil refiners.

9. A full scale market evaluation is required to determine the product demand and to fully assess the true economic value of any proposed venture in Southeast Asia. This market test would require production of large samples of a totally processed finished cooking oil.

10. Additional pilot operations are required for data development and variable optimization before a refining facility could be properly designed.

Recommendations

In view of the finding that miscella refining is feasible as applied to X-M rice oil and should contribute, without any significant increase in capital requirement, to the profitability of the X-M rice milling technology as well as to feasibility at remote locations in Southeast Asia, if Riviana and AID determine to proceed with further steps toward possible application of advanced milling technology, work should include activities to complete the development of the miscella refining technique for crude rice oils as follows:

1. Elevate the level of work to a full pilot facility including all steps to produce a finished premium quality cooking/salad oil, i.e., refining, bleaching, winterizing, deodorizing.

2. Obtain from such a pilot unit the capability to: (1) produce large scale samples for use in overseas product and consumer acceptance evaluation and (2) determination of optimum operating conditions for each processing step in order to complete process engineering and design and construction engineering.

3. Prepare to conduct a full scale product and market evaluation in one or more selected countries.

4. From such investigation, conduct an in-depth and full scale venture analysis for miscella refining of rice oil in one or more selected countries of Southeast Asia.

APPROVED

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Introduction

The X-M* process for milling of rice utilizes a hexane solvent system during milling which thereby produces a crude rice oil and rice bran oil mixture as a concomitant product. This oil can be conventionally refined to an edible salad/cooking oil. Conventional refining in Southeast Asia poses certain negatives such as toll refining fees, transportation and storage problems to an extent to render oil refining impractical in many areas of undeveloped countries. The adaptability of miscella refining to X-M processing possibly could offer major economic and nutritional advantages to Southeast Asia. An evaluation of miscella refining of rice oil as a conjunctive operation with X-M milling was conducted to determine its value with reference to conventional oil refining.

Discussion

Study of scientific publications, trade literature and applicable vendor information quickly revealed miscella refining to potentially be a technically feasible process for rice oil. Commercial plants for cottonseed and soybean oils have been developed and successfully operated in the United States and abroad. Total refining of a vegetable oil consists of removing the free fatty acids and additional low quantity compounds which contribute to color, clarity, or odor negatives. This has been accomplished by several steps which include alkali reaction with the free fatty acids (and removal of the soap stock there formed), clay bleaching of the color bodies, cold filtration for removal of crystalline materials, and high temperature steam stripping for removal of trace odoriferous compounds. Historically the major technological efforts on refining of vegetable oils have been to reduce the neutral oil (triglycerides) losses that occur during the alkali reaction of the free fatty acid and the subsequent soap separation. These losses are mainly due to the entrapment of good oil which is carried away upon removal of the soap stock. Losses also are generated by a secondary reaction in which the triglyceride esters are hydrolyzed to glycerol and free fatty acids. High gravity liquid-liquid centrifugals are normally used to perform the soap stock separation. Experience with crude rice oils has shown this problem to be very serious since the soap stock from rice oil is more fluffy and tends to trap more neutral oil than those produced by other vegetable oils.

Miscella refining differs from the above described procedure in that the alkali reaction and the centrifugal separation of the soap stock are performed with the oil in a miscella or solvent state. The differences in viscosities, relative densities, and reactant distribution patterns allow a reduction in the losses for cottonseed oil and other oils which have traditionally shown high refining losses. With the information developed above, various approaches to miscella

* Trade Mark, Food Engineering International, Inc., a subsidiary of Riviana Foods, Inc.

refining were investigated to select one which might be most adaptable to rice oil refining. The preliminary investigations of the processes were limited to those which used hexane as the solvent and had shown commercial feasibility on other oil seeds. They included (1) the De Smet Process, Antwerp, Belgium which utilizes a two solvent system to achieve separation of the soap stock from the refined oil miscella, (2) Ranchers Cotton Oil Company's process, California, U.S.A. which utilizes centrifugal separation of the soap stock formed by the alkali reaction in and following a homogenizer and (3) The De Laval Separator Company, Poughkeepsie, New York process which utilizes hermetic centrifugation for soap stock removal from the alkali reaction performed in and following high sheer mixtures. After a laboratory investigation and study of the process equipment used, the De Laval miscella refining process for cottonseed and soybean oils was selected as the one to pursue for modification applicable to rice oil refining.

Approximately 30 tests were made in the laboratory to demonstrate technical feasibility of the process for rice oil and to establish a range of effective but not optimized conditions. This data allowed the design of a pre-pilot unit for a more extensive evaluation of the product and process. The unit would also develop some of the required scale up data. The pre-pilot unit included equipment necessary for the alkali reaction, soap stock separation, partial bleaching and filtration, solvent removal and deodorization. The reaction and soap stock separation equipment were selected and designed such that the operation would be quite close to scale model of commercial plants.

Equipment for the other operations was not as sophisticated and functioned only as means to achieve recovery of a final product.

Many short duration test runs on the pre-pilot equipment were conducted in order to test and modify the equipment to establish operating conditions and to determine important indicators of the process. With this back log of information a 7½ hour continuous miscella refining run was made using grade 101 (dewaxed) rice oil containing 3.9% FFA. The miscella was then stripped of hexane, bleached, winterized and deodorized to a finished edible cooking oil. This oil was not only equal to but in minor respects superior to the finished product derived from conventionally refined X-M crude rice oil. Refer to Table I for product characteristics in comparison to conventionally refined oil.

Table I

PRODUCT CHARACTERISTICS COMPARISON OF FINISHED RICE OILS BY MISCELLA AND CONVENTIONAL REFINING

	Finished Oil By Miscella Refining (Pilot Scale Equipment)	Finished Oil By Conventional Refining (Commercial Scale Equipment)
FFA	.07 ± .02	.05
Smoke Point	495°F	500°F
Unsap.	2.45	1.7 - 2.2
Cold test	>5 hours	>5 hours
Acetone Ins.	0.0175	0.03 - 0.06
Peroxide Value	1.14	<1.0
AOM Stability	38 hours	20 hours
Iodine Value	104	103-105
Color	10Y, 1.1R	10-30Y, 1.0 - 2.0R
Sap. Value	194	185-195

Refining losses for caustic treating and soap stock separation were approximately 1½ times the FFA of the crude. Only 1.6% of the neutral oil was trapped and removed by the soap stock. This quantity of loss across the reaction and separation steps is equal to the normal operations of conventional refining of cottonseed and is far less than the conventional losses demonstrated on rice oil. Commercial losses on rice oil by conventional caustic treating and water washing have been running approximately 2.8-3.0 times the FFA content for similar crude rice oils. Therefore refining losses, across the reaction and soap stock separation steps only, for 4% FFA crude rice oil, was 6.0-6.5% by miscella refining and 11.0 - 11.5% by conventional refining. Limited cooking product performance tests indicate the finished oil prepared by miscella refining to be equivalent to and have the same premium cooking oil characteristics as commercialized Mahatma Rice Oil produced by conventional refining.

With the process and product performance demonstrated above showing so favorably, a preliminary economic evaluation was developed. A basis of a United States located, battery limits plant in conjunction with an X-M milling plant for capacities of 1,000 pounds per hour of crude oil feed was used. A 24 hour/day, 5 day/week operating schedule was assumed. It was felt that these numbers could be used as a base correlation for developing applicable costs for specific locations overseas by adjusting labor, equipment or other factors which are in different proportions to United States manufacturing cost. The economic considerations are of course approximations based on limited data and lack of a fully developed plant design. The approximation procedures used were consistent with those published in many texts on cost engineering. A fixed capital investment of $232,000 ± 30% was estimated to build a battery limits facility for miscella refining, bleaching, winterizing and deodorizing a crude rice oil stream at the rate of 1,000 pounds

per hour. No packaging costs were included. If the crude oil is assumed to have no value, a manufacturing cost of goods of 2.94¢/ pound was calculated. If the crude oil is assumed to have a value of 8.0¢/pound, an 11.69¢/pound manufacturing cost was calculated. To be meaningful these costs should be compared to those for conventional refining of the same size stream. Capital requirements are essentially equal since the savings achieved by miscella refining by elimination of the water wash and vacuum drying equipment is balanced out by the higher cost of explosion proof equipment required for solvent processing. Other production costs are quite similar except for raw materials, in that conventional refining does not experience the hexane losses in the soap stock. Therefore, with no value assigned to the crude oil a cost of goods was calculated as 3.035¢/ pound. This is 3.2% higher manufacturing cost than that for miscella refining. When the crude oil is assigned a value of 8¢ per pound the refining losses represent the cost of both product not made and purchased material lost. For this case the cost of goods for conventional refined oil is 12.27¢/ pound. This is a 5.0% higher manufacturing cost than miscella refining. See Table II for a summary of the cost information.

The data as developed shows the miscella refining of rice oil in conjunction with an X-M rice milling plant to be technologically feasible and to have a strong potential economic feasibility. It must however, be brought to the forefront that the work was performed on oil from one crop of Louisiana rice, the operating conditions and variables have not been optimized, and estimated costs are only approximate, using acceptable estimating methods but not based on firm quotes from a designed plant. The basis was for a United States plant site, which forces a re-evaluation for overseas ventures. Also, the product characteristics are evaluated in the light of requirements for the American cooking oil market.

Table II

COMPARATIVE ECONOMICS AND CONVENTIONAL REFINING OF CRUDE X-M RICE OIL

Basis: 1000 Lb/Hour Crude Feed - U.S. Battery Limits Plant

		Crude @ Zero Value		Crude @ 8¢/Lb Value	
		Miscella	Conventional	Miscella	Conventional
Investment, Fixed Capital	$	232,000	232,000	232,000	232,000
Cost of Crude, $/Day		-0-	-0-	1,920	1,920
Other Daily Cost, $/Day		646.07	630.87	646.07	630.87
Total Daily Cost, $/Day		646.07	630.87	2,566.07	2,550.87
Daily Crude Feed, Lbs		24,000	24,000	24,000	24,000
Daily Production, Finished Oil, Lbs.		21,948	20,784	21,948	20,784
Overall Yield, Finished Oil		91.45%	86.40%	91.45%	86.40%
Cost of Goods		2.94¢/lb	3.035¢/lb	11.69¢/lb	12.27¢/lb
% Increase in Manuf. Cost Over Miscella Refining		--	3.2%	--	5.0%

RIVIANA FOODS INC.

Houston, Texas

KEY FOREIGN RICE VARIETY

X-M EVALUATION

Distribution:

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Research & Development Department
Project 1.007, Report No. 2
Key Foreign Rice Variety X-M Eval
DOS Contract No. AID/csd-1583
July 1, 1968

Key Foreign Rice Variety X-M Evaluation

As outlined in the Work Plan dated 7/14/67, the project was divided into two phases. Results of the Phase I study, the evaluation of small samples in lab scale to determine the physical, chemical, and milling characteristics of the foreign varieties leading to selection of certain varieties for larger scale milling test in conventional and X-M milling, were reported in Interim Report No. 1 dated 1/25/68.

Phase II, the comparative milling of selected foreign varieties to determine the projected overall added value of X-M milling in terms of rice yields, oil and bran, has to this date been only partially completed due to problems involved in obtaining 2-3 ton quantities of rice from the far east. The results that are available at this time on the Phase II study are reported herein.

Conclusions

1. Based on only several hundred pounds of IR-8 received from the Philippines, no problems of a gross nature are expected to be encountered in either X-M or conventional milling of this particular variety. Hence, no recommendation can be offered.

General Discussion

Upon completion of Phase I of this project in January, steps were taken to obtain 2-3 tons of the following foreign rice varieties in the brown rice state.

Philippine Variety -	IR-8	
Thai Varieties -	Puang Nahk - 16	
	Leuang Pratew - 28	
	Nahng Mon S-4	

Through the help of H. M. Beachell of The International Rice Research Institute in the Philippines, several hundred pounds of IR-8 brown rice were obtained for initial trial runs on large scale conventional and X-M milling equipment. This material was not of sufficient quantity to allow yield data to be obtained for cross comparison. The several hundred pounds of IR-8, however, did indicate that no problems of a gross nature would be encountered in either conventional or X-M milling.

Two tons of IR-8 brown rice are presently in transit from the Philippines, have been received in this country but is sill in transit to the milling facilities. Problems in collecting and shipping the sizeable samples necessary for this phase of the project have been numerous.

At this time, the problems of delivery of the Thai rice varieties are such that there is no indication as to date of delivery.

Present plans for the completion of this phase of this project are unchanged from the work outline of 7/14/67 and completion of Phase II is expected shortly after receipt of the requested foreign rice varieties, presuming continuation of this project by Riviana and AID in FY '68-69.

APPROVED

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PART I -- APPENDIX

A. Materials and Methods
B. Formulations and Procedures For Preparing the Prototype Product.
C. Project Agenda
D. Bibliography

APPENDIX -A
MATERIALS AND METHODS

Protex, obtained from the solvent extraction mill in Abbeville, La. was milled from Nato and Saturn varieties of medium grain rice. It was reduced in a Pulvasizer A-2 hammermill to pass a U.S. #40 screen.

Enzymolysis was conducted in non -reactive vessels at times and temperatures closely paralleling manufacturer's recommendations. For example, the following procedure was used for the bacterial diastase, Rhozyme H-39. Protex was mixed in water to a concentration of 20% by weight. Three hundredths to 0.1% enzyme to weight of substrate was added. The mixture was brought to 80°C, cooled to 70°C and held for one to two hours. Gelatinization was accomplished through external heat rather than by direct steam injection. Several of the minor commercially available food grade diastase, cellulase and protease enzymes were screened for possible activity on Protex and Protex protein concentrates.

A De Laval basket centrifuge and the stack disc type De Laval model VO-244 separator were used for the solid-liquid and liquid-liquid separations.

All acids, bases, buffers and other chemicals were of food grade quality. Analytical procedures followed are contained in the official A.O.A.C. methods (9). For the determination of amino acids the procedure of Stalling (8) was used. 150 mg of sample were hydrolyzed in 20 ml of constant boiling HCl under nitrogen for twenty (20) hours. at 105°C. The HCl was removed by rotary evaporation. The residue was redissolved in 70.0 ml of 0.1 M HCl. A 5.0 ml aliquot was diluted to 10.0 ml with 0.5 mM norleucine (internal standard).

0.5 ml of this solution were injected onto the column of a Technicon Amino Acid Analyzer and eluted over a nineteen (19) hour period. The peak areas were determined with an Infotronics integration system.

Insight to nutritional characteristics of X-M rice bran protein concentrate were established through the animal testing facilities of The Harris Laboratories, Lincoln, Nebraska.

The protein efficiency ratio (PER) was determined for two samples of air dried protein concentrate and standard commercial casein by the following method:

1. Thirty (30) weanling male twenty-three (23) days age (Holtzman strain) served as experimental animals.

2. A randomized block design was utilized in which blocks represented variations in initial body weight. Rats were randomized in each block for diet and cage.

3. Rats were fed, ad libitum, the following diet:

A. Corn starch - 80%
B. Cottonseed oil - 10%
C. Non-nutritive cellulose - 5%
D. Salts, U.S.P. XIV - 4%
E. Vitamin mixture - 1%

1. Vitamin A - 1000 I.U. per gram
2. Vitamin D - 100 I.U. per gram
3. Vitamin E - 10 I.U. per gram
4. Vitamin K - 0.5 mg per gram
5. Thiamine - 0.5 mg per gram
6. Riboflavin - 1.0 mg per gram
7. Pyridoxine - 1.4 mg per gram
8. Pantothenic acid - 4.0 per gram
9. Niacin - 4.0 mg per gram
10. Choline - 200 mg per gram
11. Inositol - 25 mg per gram
12. Para-aminobenzoic acid - 10 mg per gram
13. Vitamin B_{12} - 2.0 mg per gram
14. Biotin - 0.02 mg per gram
15. Folic acid - 0.20 mg per gram

The protein foods under test were incorporated into their respective diets at the expense of the starch and based on their actual protein contents to make 10 per cent protein (Nx6.25).

All three protein sources were analyzed.

4. Three diets were prepared, one (1) with basal diet (step 3) plus casein. This diet served as a reference standard group diet, and one (1) each containing the basal diet plus air dried protein isolate or heat dried protein isolate.

5. Weekly and ten (10) day records of feed consumption and body weights were recorded. The total gain in body weight and the total protein consumptions were calculated and used to determine the PER of all three (3) diets and the PER of the two tested protein isolates were expressed as percentages of their corresponding casein diets in each block. The following formuli were used:

$$\text{PER} = \frac{\text{gain of test animal (grams)}}{\text{Protein consumed (grams)}}$$

$$\text{PER of Air of Heat dried as \% of casein PER} = \frac{\text{PER of Test Diet} \times 100}{\text{PER of Casein}}$$

6. The project was terminated after four (4) weeks. The individual PER values were calculated for each experimental unit.

APPENDIX B
FORMULATIONS AND PROCEDURES FOR PREPARING THE PROTOTYPE PRODUCTS.

Baked Coating For Soft Center

Ingredients

Flour (wheat patent flour)	400 g.
Protex (finely ground)	200 g.
Sucrose	100 g.
Invert Sugar	30 g.
Shortening	50 g.
Salt	6 g.
Baking Soda	5 g.
Ammonium bicarbonate	2 g.

The above ingredients are kneaded using a Hobart or similar mixer for 5 minutes forming a homogenious dough which is then rolled into thin sheets. Strips are cut and wrapped around a soft center and baked at 400°F for 10 minutes.

High Protein Caramel
Soft Center Formula

Ingredients	
Sucrose	1000 g.
Invert Sugar	1000 g. (45% Solids, Syrup)
Rice Protein Concentrate Gel form	3000 g.
Rice Oil	118 g.
Vanilla Flavoring	1 g.
Butter Flavor	1 g.
Water	500 g.

Ingredients are blended and concentrated by heating to 240°F. Flavoring is added at the last part of the cook. The batch is then poured onto a cold slab and cut to appropriate size pieces for subsequent coating.

Fried Snack Product

Ingredients

Protex	1000 g.
Medium Grain Rice Flour	2000 g.
Water	1400 g.

Flour mix and water are blended thoroughly then the material is extruded through a slit shaped die to form a partially gelatinized ribbon. Heat formed during extrusion will raise the temperature to + 212°F. The puffed snack is formed by taking the dough ribbon immediately after extrusion and frying it at 400°F for 45 seconds. The snack is then salted and seasoned with about 2% (wt.) of a seasoning base. This product when stored in a moisture tight package atmosphere retains a fresh crisp texture for over 6 months.

High Protein Fried Snack

Ingredients

Rice Flour, Medium Grain	2650 g.
Dry Rice Protein (70% Protein)	1000 g,
Water	1700 g.

The base extruded product is prepared under the same conditions as that described for the high protein noodle product. The primary difference being the rice flour used is from medium grain rice. This flour puffs much better than the par-boiled rice flour or long grain rice flour and gives an improved texture.

The extruded dough ribbons are immediately immersed in hot oil for puffing at 400°F for 15 seconds. This product cooks much quicker than the intact Protex snack. The bland base snack may now be either salted or salted and seasoned with various flavors. Protein content on a dry weight basis is about 25%.

High Protein Noodle

Ingredients

Parboiled Rice flour	2650 g
Dry Rice Protein Concentrate (70% Protein)	1000 g.
Water	1700 g.

Mix the ingredients to a uniform blend of flour and water then extrude at +212°F. A ribbon shape die is used for the noodle product. The extruded ribbon should be thoroughly gelatinized forming a plastic ribbon of dough. This can be pre-dried in a Procter-Schwartz laboratory cabinet type or similar dryer for 10 minutes at 180°F. The product should be allowed to "rest" for 2 hours in order for internal moisture to reach equilibrium with surface moisture. This prevents stress from resulting internally in the product which ultimately will cause the product to crack and check on the surface. The pre-dried product after the rest period is placed in the forced air dryer again but with ambient air to remove the final moisture. This step requires about 24 hours to reach a moisture content of approximately 12%. The resulting product contains 25% protein and may be cooked by boiling in 2% salt water for 20 minutes. The product has flavor and texture similar to commercial egg noodles.

Hard Candy Coating For Soft Centered Product

Ingredients

Sucrose	1000 g.
Dextrose	250 g.
Water	250 g.

Ingredients are cooked to 290°F in an open kettle with stirring. This syrup is then used directly to coat soft centers. A simple hand method for coating centers is to secure it to a toothpick for handling during dipping into the molten sugar. As this coating hardens the toothpick is removed and the piece may be rolled in sucrose crystals. This will give the candy piece a much greater resistance to high humidity. Product that has been stored in moisture free packages shows no sign of tackiness after an excess of 6 months storage.

Rice Milk Caramel
Basic Formula

Rice Milk

%	Ingredient		
20.0	White Sugar	152	g.
4.0	Water	30	
43.1	Corn Syrup	328	
7.4	Margarine	56	
24.9	"Rice milk" concentrate	189	
0.5	Sodium Chloride	4	
0.1	Vanilla Extract	1	
100 %		760	g.

Estimated batch yield = 500 g.

Procedure: Sucrose, corn syrup, margarine, and sodium chloride are mixed and brought to a boil. The "rice milk" is added to the boiling sugar and oil very slowly. Cow's milk is much more sensitive to the heat than the rice milk in such a step. Little precaution is needed when adding the rice milk but unless extreme care is taken when cow's milk is added to the boiling sugar solution there would be coagulation of the protein and a grainy texture would result.

After milk is added the mixture is cooked down until the temperature reaches 240°F. At this point the molten mix is poured onto a cold slab and allowed to cool. The sheet is cut into pieces suitable for wrapping or subsequent coating.

APPENDIX D
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APPENDIX C

PROJECT AGENDA FY '67-68

Project 7.003 DEVELOPMENT OF NUTRITIOUS, PROTEIN-RICH CONSUMER FOOD PRODUCTS FOR S.E. ASIA BASED ON X-M RICE BRAN

DOS Contract No. A.I.D./csd-1583

GENERAL OBJECTIVE

To develop several nutritious consumer food products based on projected availability of a source of X-M rice bran oriented toward use of other inexpensive raw materials in S. E. Asia, including "bar good" products and a beverage.

BACKGROUND AND SIGNIFICANCE

Conventional rice bran is extremely unstable in storage, contains about 12% protein, is bitter and branny in flavor, typically is bacteriologically unclean and, because of these and related factors, has not been successfully employed as a human food ingredient despite its abundant availability even in the heavy rice consuming areas of S. E. Asia. The new X-M bran, on the other hand, is characterized by a bland, almost sweet flavor, is relatively white and clean looking, is vastly more stable and can easily be stabilized further for storage or usage in food processing and contains 18 - 20% protein with a good amino acid balance.

1. The Agency for International Development has estimated that in the developing countries there are some 667 million children under 15 years of age and currently some 269 million are suffering serious malnutrition. The Food for Peace donations reach about 15% of the 7 to 14 years group with milk and grain foods, but only 2% of the pre-school group are reached.

Nutritionally deprived children are found in Asia, Latin America, and Africa's developing areas. A protein-rich food supplement that is derived from rice would not be foreign to any group. Such a supplement ideally would lend itself to addition added to the diet as a dry powder which can be prepared into a colloid-like milk type drink or as a base for soup type products or gruels. Such a material can be made from the portion of the rice kernal which until now has been discarded, but contains in excess of 20% protein, most of the grain's vitamin content, required minerals such as calcium and phosphorus and finally, is an excellent energy source. The fiber content is low enough to be non-irritating to the gut.

2. Wafers, crackers, biscuits and bar goods are found and accepted in almost all cultures. Many areas with substandard transportation and little refrigeration are unable to utilize fruit and vegetable crops other than to the extent which they can be

consumed or sold locally before spoilage.

Products with moderate shelf life can be utilized in developing countries by being incorporated into distribution systems such as the street hawkers of Thailand, Philippines, Indonesia, etc., and the peddlers of Latin America. High acceptance of fruit flavored foods already exists in these areas.

SCOPE

This project is to be directed to explore the feasibility of capturing the advantages inherent in the new, relatively stable high-protein X-M rice bran to develop human food products using X-M bran as a raw material or important ingredient which will be acceptable to consumers, particular reference to S. E. Asia but with relevance elsewhere as well.

TIMING

This project, which is part of A.I.D./csd-1583, must be completed before June 30, 1968 to the point of recommendation in detail for such economic studies, large scale product tests, market tests, further product development or engineering work as may be required in Phase II and Phase III.

SPECIFIC OBJECTIVES

1. To develop background information on regional preferences in fruits, vegetables and protein food plus existing Technologies through search of scientific, legal, commercial, and socio-economic literature.

2. To obtain samples of beverage and dried and/or baked foods currently eaten to establish characteristics of flavor, texture, shape etc. with sufficient objectivity to define model products for development.

3. Based on the accumulated information obtained in Specific Objectives 1 and 2 and on known chemical, physical and nutritional properties of X-M rice bran to identify the product concepts and development approaches most likely to find acceptance by the intended users.

4. To investigate the technical, nutritional, and economic feasibility of a beverage concept and a solid food concept in the laboratory and to develop the process for making prototypes through pilot plant studies of sufficient size to produce samples for preliminary nutritional performance and acceptance information as well as the necessary data to permit an exploratory economic evaluation of the products.

5. If warranted by progress in attaining the other objectives develop the requirements for Phase II to carry highly promising products through further development, acceptance tests, and test markets.

BUDGET

Phase I $71,000

PART II - APPENDIX

A. Literature Survey & Bibliography
B. Laboratory Investigations
C. Pre-Pilot Investigations
D. Economic Considerations

APPENDIX - A
LITERATURE SURVEY

A review of the scientific literature, trade publications, vendor equipment data and sales representatives' discussions was conducted. This provided the background information on the various aspects of miscella refining and conventional refining of vegetable oil necessary to initiate preliminary laboratory investigations. The survey revealed considerable work had been done on miscella refining with particular emphasis on cottonseed oil and some activity on soybean oil. Miscella refining of cottonseed oil had in fact been commercialized and is presently practiced both in the United States and abroad. Three companies offering commercialized miscella refining technology are De Smet, Antwerp, Belgium; Ranchers Cotton Oil Company, California and the De Laval Separator Company, Poughkeepsie, New York.

In each case, refining consists of reacting the free fatty acids in the crude oil with alkali (usually sodium hydroxide), followed by removal of the soaps from the reaction. Additional reactions by refining include partial bleaching of the oil and removal of the compounds generally characterized as gums, waxes, phosphatides, and other nonglyceride components present in minor quantities.

The process patented by Ranchers Cotton Oil Company utilizes a homogenizer to achieve the dispersion required for good reaction between the water caustic layer and the miscella. This results in an emulsion of the formed soap stock and oil bearing miscella. The emulsion is broken by a series of heating and cooling exchangers which are reported to result in a stream which can be separated by liquid-liquid centrifugals. These two steps are the key to the process, (1) dispersion and reaction of the two non-miscible layers followed by (2) efficient separation of the soap stock from the neutral oil miscella. A Sharples non-hermetic type centrifuge is used to achieve the separation. There is at least one commercial installation in operation in the United States using this process for the refining of cottonseed oil. It is believed the capital expense for equipment required to achieve the reaction and break the emulsion is high compared to other methods of oil refining.

De Smet, A large European oil refining equipment supplier, has a process utilizing a two solvent system to achieve the separation of soap stock from cottonseed miscella. Caustic, crude oil, hexane and alcohol are fed to a mixer in which the reaction takes place. This mixture is allowed to decant with the neutral oil remaining in the hexane and going overhead. The alcohol/water/soap stock layer is removed by bottom discharge. A third layer at the interface reportedly containing the gums is drawn off from the middle of the vessel. Both the heavy phase and the light phase layers require a washing step followed by a secondary decanting. This approach does provide a continuous process free of the problems of centrifugal separation; however, again the capital investment required for these key steps would appear to be relatively high. Further, although this company has mainly European operations it has no known miscella refining units operating in the United States. They report their process should be convertable from cottonseed to rice oil processing.

The De Laval Separator Company, a manufacturer of vegetable oil refining equipment has a patented vegetable oil miscella refining process which utilizes an hermetic certrifuge to achieve miscella/soap stock separation from a carefully controlled mixing/reaction operation. Several cottonseed oil miscella refining plants within the United States are operated using this process.

In cottonseed oil refining, miscella refining reportedly results in a one to three percent less refining loss than conventional refining, depending upon the nature of the crude. The advantages of miscella refining are highest for low quality crudes. For soybean oil refining the advantage of miscella refining lies in color rather than improved refining loss since soybean oil, characteristically, has a low refining loss.

Outside of the processing concepts covered by the above three companies the literature found is limited to more exotic or unproven approaches to miscella refining of vegetable oils. The literature also indicates the chemical differences in rice oils from world wide rice varieties is minor and should not impose drastic changes in processing methods. A selected bibliography of the related literature is listed below.

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APPENDIX B
LABORATORY INVESTIGATIONS

Preliminary laboratory investigations of the De Smet two solvent system indicate requirements to achieve a decantable extractive solvent stream are most strenuous. The procedures used were unable to control the strong tendency of rice oil, hexane and water to form a stable emulsion.

Test operation of a Sharples Corporation laboratory scale centrifuge for stream separation as employed by The Ranchers Cotton Oil Company was conducted. A separation was achieved with significant atmospheric hexane losses and a semi-continuous soap stock discharge. Study of the process equipment (homogenization followed by thermo-cycling for the reaction) indicates high capital investment requirements.

Studies following the De Laval Cottonseed Oil process on rice oil miscella and using a laboratory Gyrotester Separator showed this approach combined with other required refining steps such as filtering, bleaching and deodorizing to be potentially promising for modification to rice oil miscella refining.

Approximately thirty tests were made in which crude rice oil was refined, bleached and filtered, following the basic reaction and separation methods disclosed in the De Laval process. The variables studied included reactor type, phosphate treatment, caustic treatment, reaction time, reaction temperature, and miscella oil concentration. The procedure followed is briefly outlined below:

1. Make up 500-600 ml of miscella.
2. Warm to selected reaction temperature.
3. Begin mixing.
4. Acidify, (optional)
5. Add caustic.
6. Hold for selected reaction time.
7. Separate with gyrotester or filter.
8. Reheat and bleach.
9. Filter
10. Analyze for free fatty acid.

The data obtained from the laboratory investigations shows an effective range of conditions for the major variables based on removal of free fatty acids from the neutral oil.

Three different stirrer types were used to serve as the mixing and reacting vessel. The need for acid treating was not confirmed or rejected. Run No. 26 represents a typical run in the effective (but not optimized) range of operating conditions.

Crude rice oil (1000 grams) containing 3.57% free fatty acids was blended to a 50/50 wt. % hexane miscella. No acid treatment was

utilized. The miscella was heated to 140°F and 20° Bé caustic solution was added at 1.17 times stoichiometric amounts. The reaction was continued for 10 minutes under high speed mixing. The sample was then filtered through a bed of filter aid and asbestos fibers. The filtrate was bleached with 75 grams of Millwhite Morac clay for 20 minutes at 100-140°F. The clay was removed by paper filtration and hexane removed by vacuum stripping. The product oil contained 0.04% FFA and had a 1.1 Red Lovibond color. Refer to Tables B-I and B-II for details of other test conditions and resulting data from these tests.

No significant yield data was determined on the laboratory tests due to the inherent limitations of laboratory equipment and related handling losses.

Table B-I

ANALYTICAL RESULTS OF LABORATORY
MISCELLA REFINING OF RICE OIL

FFA (Final)	RUN
.025 %	27
.030	3
.030	23
.030	24
.030	25
.040	6
.040	7
.040	28
.040	10
.040	26
.040	19A
.050	19B
.050	20
.060	29
.060	30
.070	21
.080	16
.090	5
.090	22
.120	8
.180	9
.180	15
.200	11
.220	2
.230	17
.320	18
.350	14
.440	1
.470	13
.750	4

TABLE B-II

LABORATORY MISCELLA REFINING OPERATING CONDITIONS

	Operating Conditions	Run No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AGITATION	Stirrer, Hot H_2O Bath	X	X	X	X	X	X									X	X	X	X												
	Waring Blendor							X	X	X	X	X		X	X					X	X	X	X	X	X	X		X	X	X	X
	High Speed Stirrer																										X				
ACETIC ACID	0.0 ppm							X								X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	700 ppm	X	X	X	X	X	X																								
	1000 ppm								X		X	X		X	X																
	3000 ppm									X																					
NaOH ADDED (20° Bé Sol'n)	1.02 X Stoich.																						X								
	1.05 " "														X	X															
	1.09 " "																X														
	1.13 " "																			X		X		X	X	X					
	1.15 " "																											X	X	X	X
	1.17 " "																										X				
	1.32 " "																	X	X												
	1.37 " "																				X										
	1.56 " "																X														
	2.23 " "							X	X	X	X	X																			
	2.57 " "	X	X	X																											
	2.69 " "				X	X	X																								
REACT. TIME	3 Min.											X																			
	6 "	X	X	X	X	X	X	X	X	X																					
	10 "										X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
OIL START	1.93% FFA, 0.13% A.I., 0.06% I.I.																														
	3.42% " 0.24% A.I., 0.06% "							X	X	X	X	X		X	X													X			
	3.45% " 0.21% A.I., 0.11% "																												X	X	X
	3.57% " 0.18% A.I., 0.06% "															X	X	X	X	X	X	X	X	X	X	X	X				
	5.16% " 0.38% A.I., 0.05% "				X	X	X																								
OIL WT.	250 g.	X			X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X
	500g.		X	X															X												
	1000 g.																										X				
MISC. CNC.	35%	X			X																										
	50%		X			X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	65%			X			X																								

TABLE B-II

	Operating Conditions	Run No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
TEMPERATURE, START	19.0°C																													X	
	40.0																														X
	54.5	X																													
	55.0		X																												
	55.8			X																											
	56.0				X																										
	57.0					X																									
	57.5						X																								
	58.0															X	X	X	X												
	60.0							X	X	X	X	X		X	X					X	X	X	X	X	X	X	X	X	X		
SEP.*	Gyrotester Separation	X	X	X	X	X	X	X	X	X	X	X		X	X																
	Filtered (without Gyro Stp)															X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BLEACH	Vegaclay - I	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X								
	Milwhite Palex																							X							
	Milwhite Morac																								X		X	X	X	X	X
	Activated Charcoal																									X					
OIL OT.	0.050% FFA or Less			X			X	X			X									X	X			X	X	X	X	X	X		
	Between 0.050% & 0.100% FFA					X											X					X	X							X	X
	0.100% FFA or More	X	X		X				X	X		X		X	X	X		X	X												

* Method of soap stock separation.

APPENDIX C
PRE-PILOT SCALE INVESTIGATIONS

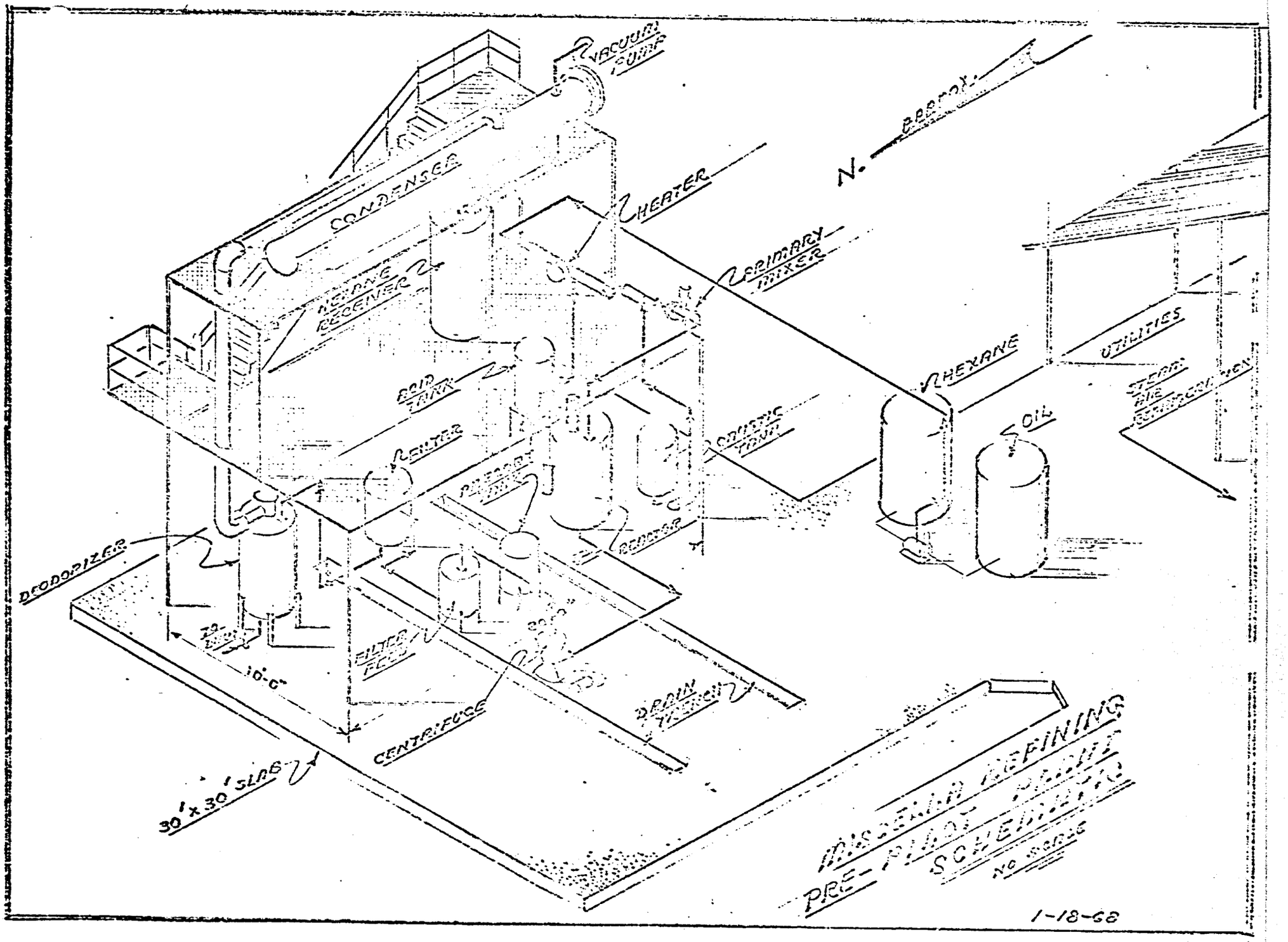
Pre-Pilot Unit Design and Construction

With the results of the laboratory study, sufficient information was accumulated to permit design of a pre-pilot unit. The design was based on the following expected operations. Oil and hexane are blended to a controlled miscella concentration and warmed to approximately 120°F. An acidification step meters reaction solution in the parts per million range to the miscella. Immediately following, caustic is then metered in and mixed with an effective controllable in-line blender. A well designed mixing operation is essential to the process, for it is preferred to achieve an intimate dispersion of the reactants without forming a stable emulsion. The mixed stream is then fed to a stirred reactor for a controlled contact time to complete the desired reactions. Reactor effluent is fed to a liquid-liquid hermetic pressurized centrifuge in which the soap stock is separated from the neutral oil miscella. The clarified miscella is then fed to a horizontal plate filter for a combination of filtering and bleaching which will utilize filter paper and bleaching clay. The bleached product is then accumulated in a stripper-deodorizer to be operated as a batch unit. Hexane is removed under vacuum, condensed and returned to storage after separation of water from the sparge steam. At this point a higher vacuum and higher temperature are utilized for deodorization. The product is placed in drums for storage.

The pre-pilot unit is an outdoor unit utilizing scaled down commercial equipment which can generate much of the data required for commercial engineering design. The process is continuous through bleaching; however, batch operation of the individual steps can be employed for tests. Batch solvent stripping and deodorizing is utilized in order to control capital cost of the pre-pilot unit. This unit has a maximum capacity of approximately one 55 gallon drum of oil per day based on an eight hour operating day, with a miscella feed rate of 30 gallons an hour. Refer to the pre-pilot plant schematic drawing for layout of the equipment. Due to the hazards of hexane vapors all equipment in the pre-pilot unit process area is of explosion proof design.

Materials of construction are carbon steel with the exception of the deodorizer and centrifuge. Stainless steel construction is reportedly required for the deodorizer because of flavor problems attributed to be imparted by mild steel at deodorizing temperatures. Stainless steel is the standard material of construction of this type of centrifuge. Utilities required and installed for this unit include 300 psig steam, refrigeration, compressed air, water and vacuum.

The unit is instrumented to allow for control of the major variables, and arranged such that individual processing steps can be studied without running the total unit.


VACUUM PUMP
CONDENSER
HEATER
N.
PRIMARY MIXER
HEXANE RECEIVER
UTILITIES
HEXANE
OIL
FILTER
CENTRIFUGE
DEODORIZER
10'-0"
30' x 30' SLAB
DRAIN
1-18-68

Pre-Pilot Operations

Construction and preliminary testing of the pre-pilot unit was completed in late January 1968. During the following several months, 14 test runs of differing levels of comprehensiveness were conducted. Initial activities were concentrated on solving the mechanical problems of the equipment typical of this scale research activity. In parallel and subsequent to this first phase, efforts were directed toward determining effective (but not optimized) operating conditions for the critical variables.

Investigations soon revealed two basic problems in the design of the equipment, the first of these was in the combination filter-bleaching operation. The purpose was to filter trace soap stock carry over from the clarified refined miscella (coming from the centrifuge) and to perform the bleaching step required to produce an acceptable light colored cooking oil. The equipment used was a 13 horizontal tray filter precoated with filter aid and a vegetable oil bleaching clay. All efforts to achieve acceptable bleaching were unsuccessful even at temperatures approaching the boiling point of hexane. This design approach was used as a compromise with cost of time and money. The failure to bleach is attributed to insufficient contact of the bleaching clay and the color bodies in the oil. The laboratory investigations did show effective miscella bleaching based on an agitated bleaching vessel, therefore the potential utilization of miscella bleaching should not be discarded based on the difficulties experienced with this unit.

The second major design inadequacy was with the deodorization equipment, all efforts to deodorize were unsuccessful. Here again, selection was compromised with delivery time and cost for equipment with the required design sophistication. The suspected inadequacies were insufficient vacuum, (due to leakage of the used equipment purchased), lack of entrainment control, sparge steam distribution patterns, insufficient heating methods and sparge steam cleanliness. These problems could undoubtedly have been resolved; however, deodorization was only a part of the process to provide a mechanism to produce a finished oil and was not considered as a developmental activity of the project.

Aside from these two problem areas, the remaining equipment functioned well and did provide the basic effective requirements for miscella refining and a mechanism for production of a sufficient sample for further processing to a finished oil which could be evaluated in comparison to other finished vegetable cooking oils.

A continuous 7½ hour test on the refining unit was made April 29, 1968. This was run #14. Selection of the operating conditions used were developed from the 13 previous runs. A 50 wt. % oil, 50 wt. % hexane miscella was fed to the unit at a rate of 38 gallons per hour. The crude oil contained approximately 4.0% free fatty acid. The miscella was heated to 135°F, mixed with 12 ml per minute (3 lbs of solids/100 lbs of oil) of a water solution of poly-sodium phosphate. Immediately,

100 ml per minute of 18° Bé caustic (3 lbs of caustic solids per 100 lbs of oil) were injected into the miscella stream and mixed with a special high sheer "in-line" mixer to achieve an intimate dispersion of the water phase with the miscella. This stream was then allowed to react in a stirred vessel with continuous feed and effluent for an effective contact time of 16 minutes. Effluent from the reactor was pumped to the centrifuge to give a 100 psig back pressure on the centrifuge light phase. Temperature of the reactor was maintained at 138-150°F. This allowed the effluent stream to enter the centrifuge hot. The temperature in the centrifuge was critical to obtain a clean separation of soap stock from the refined oil miscella. A centrifuge temperature change of 10°F from the temperature range of the reactor, significantly affected the realtive gravities of the two phases such that soap stock would begin to be insufficiently removed from the miscella or the miscella would begin to be lost with the soap stock phase in significant quantities. The clarified miscella was pressured through the filter to achieve a slight bleaching step and removal of the trace carry over of soap stock. Millwhites, Palax, V.O.C., was used as the bleaching clay on the filter. Soap stock was collected and weighed over the entire run. Miscella feed rate was determined by calibrated tank readings. The refined miscella was then stripped of hexane, oil bleached, winterized and deodorized. The FFA content of the oil from the centrifuge was analyzed at .08 wt. %. The soap stock entrapped 1.6% of the neutral oil feed.

The attached tables show the detailed run c
and various operations performed.

Table C-I

PRE-PILOT UNIT OPERATING CONDITIONS
FOR TEST RUNS ON REACTION AND SOAP
STOCK SEPARATION

Run No.	Miscella Feed			Pretreatment		Caustic Treatment			Reactor Contact Time, Minutes	Product % FFA Oil Basis
	% FFA Oil Basis	Gallon Miscella Per Hour	Pounds Oil Per Hour	Ml. Per Minute	Pounds Phosphate Per 100 lb Oil	Ml. Per Minute	Pounds Caustic Per 100 lb Oil	Molar Ratio Hydroxyl Group to FFA		
#3	2.1	24	76.6	3	0.13	70	1.68	7	8	alkaline
#4	1.9	24	76.6	3	0.13	17	0.41	1.6	8	0.04
#7	2.3	24	76.6	3	0.13	17	0.41	1.6	8-12	0.05
#10	3.6	24	76.6	3	0.13	17	0.41	1.6	10-14	0.28
#11	4.0	40	128	5	0.13	34	0.51	0.8	9	1.7
#12	4.0	40	128	5	0.13	64	1.0	1.5	10	0.3
#13A	4.0	40	128	5	0.13	85	1.3	2.0	16	0.15
#13B	4.0	40	128	12	0.3	100	1.5	2.4	16	0.06
#14	3.9	38	121	12	0.3	100	1.5	2.4	16	0.04

Table C-II

TEST RUN #14, OPERATING DATA

Time, P.M.	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00
Hexane flow rate, gal/hour	22.6	22.6	22.6	22.6	22.6	22.6	22.5	22.6	22.6
Oil flow rate, gal/hour	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4
Miscella pre-heat temperature, °F	139	135	120	134	132	137	135	135	155
Pre-treat flow rate, ml./minute	12	12	12	12	12	12	12	12	12
Caustic flow rate, ml. /minute	100	100	100	100	100	100	100	100	100
Caustic-miscella mixer setting	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum
Reactor mixer setting	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum
Reactor temperature, °F	154	148	138	150	143	138	142	150	164
Reactor pressure, psig.	--	5	3	6	4	4	5	7	5
Contact time in reactor, minute	14	16	16	16	16	16	16	16	16
Temperature into centrifuge, °F	120	141	136	148	140	137	138	138	160
Temperature out of centrifuge, °F	--	114	119	122	118	116	116	120	140
Back-pressure on centrifuge, psig.	130	130	130	125	125	126	110	110	110

Table C-III

TEST RUN #14, ANALYTICAL DATA

The run was 7½ hours in duration.
During the complete run 887 pounds of oil passed through the centrifuge.
During the complete run 210 pounds of soap stock passed out of the centrifuge.

I Miscella Analysis, Performed and Reported on 100% Oil Basis:

	Crude X-M Oil Feed	Refined X-M Oil (before stripping)	Refined X-M Oil (After stripping)
FFA	3.90	0.06	0.08
Phosphatides	0.0249	0.0123	0.00
Unsaponifiables	2.86	2.11	2.08
Wax	0.128	0.13	0.08
Insolubles	0.050	0.02	0.26
Soap	--	0.000026	0.00033

II Soap Stock Analysis:

	Sample #1 taken @ 3:15	Sample #2 taken @ 5:00	Sample #3 taken @ 7:30	Average of Sample 1,2,3
Water	41.8	41.7	39.3	40.9
Hexane	7.3	4.9	7.5	6.6
Oil	6.8	6.7	6.7	6.7
Soap (by difference)	44.1	46.7	46.5	45.8

III Lovibond Color Readings:

	Crude X-M Oil (feed)		Refined X-M Oil (out of centrifuge)		Refined X-M Oil (out of filter)	
	red	yellow	red	yellow	red	yellow
Sample #1 taken @ 3:15	>10	>100	6.0	73	7.1	50
Sample #2 taken @ 5:00	>10	>100	>10	>100	8.5	78
Sample #3 taken @ 7:30	>10	>100	>10	>100	8.9	79

Table C-IV

EXPERIMENTAL EVALUATION OF COMPLETELY PROCESSED MISCELLA REFINED OIL FROM RUN #14 AFTER BLEACHING, WINTERIZING AND DEODORIZING.

Analytical Data

Color	10 Yellow 1.1 Red
FFA	0.076 wt. %
Smoke Point	495°F
Moisture & Volatile	0.00%
Iodine Value	104
Unsaponifiables	2.45%
Saponification Value	194
Acetone Insolubles	0.0175 wt. %
Peroxide Value	1.14
AOM Stability	33 hours
Cold Test	Greater than 12 hour

Cooking Tests:

Performance tested against conventionally refined Mahatma Rice Oil by deep fat frying of french cut potatoes and breaded shrimp.

During heating, miscella refined oil was lighter in color and had a cleaner less heavy odor.

The fried foods were judged comparable in flavor, appearance, and oiliness by an informal panel.

No negatives were noted.

APPENDIX D
ECONOMIC CONSIDERATIONS

The potentially encouraging results of the experimental investigations must be evaluated in the light of the economics involved. Capital requirements and manufacturing operating costs are developed for both a miscella refining facility and for a conventional refining facility either of which would be operated in conjunction with an X-M rice milling plant. The estimates are presented as preliminary estimates using accepted techniques for estimating plant cost when available information is limited. The costs were developed on the basis of a plant located in the continental United States. This basis was chosen due to the difficulty of determining representative cost for overseas operations, particularly a Southeast Asian operation. This approach should provide the basic factors required for modification of the estimate to an estimate applicable to specific countries with their respective governmental restrictions, availability and cost of man power, and any unique circumstances which might significantly affect equipment costs.

A plant capacity was selected as 1,000 lbs per hour of crude X-M rice oil feed to the unit. This capacity might represent a rather large plant in the underdeveloped rice producing nations. However, 1,000 lbs per hour is very small for a United States refining operation and represents a generally accepted minimum plant size. Reductions to levels below this would have only minor effect on the required capital investment and a negligible effect on the cost of man power.

To provide perspective on the above problem, costs were calculated with differing values or captive charges, of the crude oil to the refining operations. The first case assumed no charge for the crude oil. The second case uses a more practical base of 8¢ per pound for the crude as a raw material cost. No credit was given for the soap stock by-product since it is assumed that income from this stream would approximately match the cost of handling the stream.

An operating basis of 24 hours, 5 days per week, 250 days per year production schedule was used. This allows 50 weekends and two full weeks for make up of lost production time throughout a given year. Daily cost reported are costs per operating day rather than calendar day, therefore annual costs are 250 times daily cost. Each facility included the required equipment to produce a completely finished cooking oil, i.e., refining, bleaching, winterizing and deodorizing. Cost of packaging the product for a retail trade is not included. Direct operating labor was estimated at 2 men per shift plus one man per day supervision plus 4 hours per day of laboratory or analytical services.

Table II in the text of the report summarizes the economic data developed. Attachments that follow show a breakdown for capital investment, plant yields, and manufacturing cost for a total facility utilizing miscella refining and conventional refining.

Table D-I

MISCELLA REFINING

CAPITAL INVESTMENT* ESTIMATE

Purchased Equipment		
Miscella Refining & Bleaching	52,000	
Solvent Stripping*	10,000	
Winterizing	20,000	
Deodorization	35,000	
Sub Total		117,000
Installation of Equipment (Total)	75,000	
Auxiliary & Storage Facilities	10,000	
Total Physical Cost		202,000
Engineering & Contractors Fees	10,000	
Contingency	20,000	
Fixed Capital Cost		232,000

*Charged only for cost of final stripping - modified design of X-M milling facility will carry burden of solvent recovery and initial concentration of miscella.

Table D-II

MISCELLA REFINING

MATERIAL BALANCE

Basis: 1,000 lbs/hr crude dewaxed rice oil.
Operations of 24 hr/day, 5 days/week = 250 days/year.

Analysis, Wt. %

Component	Crude	Refined	Finished
FFA	3.90	0.08	0.07
Phosphatides	0.02	Nil	Nil
Unsaponifiables	2.870	2.10	2.45
Acetone Insolubles	0.10	0.10	0.01
Insoluble Impurities	0.05	0.02	Nil

Soap Stock Analysis, Wt. %

Water	40.9
Hexane	6.4
Neutral Oil	6.7
Others	46.0
	100.0%

Neutral Oil Lost in Soap Stock

$$\frac{(100)\ (.067)\ (210\text{ lb soap stock})}{(887\text{ lb crude oil})} = 1.6\%\text{ oil feed}$$

Losses

	Wt % of Crude Feed		
Refining	3.82 + .77 + .03 + 1.6	=	6.22
Bleaching	(.6 + .2) (.942)	=	0.75
Winterization	(1.0 + .2) (.935)	=	1.12
Deodorization	(0.5) (.923)	=	0.46
	Total		8.55 % of crude oil

$$\text{Hexane} = \frac{(.064)\ (210)}{(897)} = 0.0151$$ lb hexane/lb crude oil feed lost from centrifuge.

Table D-1I

STREAM SUMMARY

	lbs/hr	lbs/24 hr Day	lbs/yr
Feeds			
Crude Oil	1000	24,000	6,000 MM
Hexane (Net)	15	360	90,000
Caustic	15	360	90,000
Sodium Phosphate	3	72	18,000
Products			
Finished Oil	914.5	21,948	5.487

TABLE D III

MISCELLA REFINING PRODUCT COST BREAKDOWN

Basis: Crude oil feed at no charge.

Direct Product Costs		
Raw Materials	$ 98.00	
Direct Labor	174.00	
Maintenance	46.40	
Operating Supplies	7.00	
Utilities	75.00	
Sub Total		401.00
Fixed Charges		
Property Taxes, Insurance	18.56	
Depreciation	77.33	
Financing, Interest	55.68	
Sub Total		151.57
Plant Overhead		
Control Laboratory	12.00	
Personnel Expenses	81.50	
Sub Total		93.50
TOTAL PRODUCT COST		646.07
COST OF GOODS =		2.94¢/lb

Table D-1V

CONVENTIONAL REFINING
MATERIAL BALANCE

Basis: 1000 lb/hr Crude dewaxed Rice Oil, Operation of 24 hr/day, 5days/week

Losses by conventional refining of similar crude rice oils are equivalent to those for miscella oil processing except on refining. Caustic treatment and water wash losses are approximately 2.85 X FFA content.

Therefore 3.9 X 2.85 = 11.1% refining loss across the centrifugals. Total plant losses for conventional processing =

11.1 + .74 + 1.11 + .45 = 13.4 % of feed oil.

Therefore 1000 lbs/hr crude oil would then yield 866 lb/hr (20784 lb/day) finished cooking oil. No hexane losses would be involved. Other raw material, capital and labor are expected to be equivalent.

Conventional refining manufacturing expenses differ from miscella refining expenses by removal of:

$10.20/day of hexane and $5.00/day of poly-sodium phosphate, which reduces the daily raw material cost to $82.80 total.

Streams

	lbs/hr	lbs/24 hr. Day	lbs/yr
Crude Oil Feed	1000	24,000	6.00 MM
Caustic Feed	15	360	90,000
Finished Oil	866	20,784	5.20 MM

Table D-V

CONVENTIONAL REFINING
PRODUCT COST BREAKDOWN

Basis: Crude Oil Feed At No Charge

Direct Product Costs			
Raw Materials		$ 82.80	
Direct Labor		174.60	
Maintenance		46.40	
Operating Supplies		7.00	
Utilities		75.00	
	Sub Total		$ 385.80
Fixed Charges			
Property taxes, Insurance		18.56	
Depreciation		77.33	
Financing, Interest		55.68	
	Sub Total		$ 151.57
Plant Overhead			
Control Laboratory		12.00	
Personnel Expense		81.50	
	Sub Total		$ 93.50
	TOTAL PRODUCT COST		$ 630.87
	COST OF GOODS		$ 3.035¢/lb

Table D-VI

MISCELLA AND CONVENTIONAL
REFINING
COST OF GOODS

Basis: 8¢/Lb Charge for Crude Feed Oil

	Miscella	Conventional
Cost of Crude $/Day	$ 1920.00	1920.00
Other Daily Cost $/Day	646.07	630.87
Total Daily Cost, $/Day	$ 2566.07	2550.87
Daily Production of Oil	21948 lbs	20,784 lbs
Cost of Goods	11.69¢/lb	12.27 ¢/lb