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Interregional Seminar on the
Industrial Processing of Rice

Madras 1971 Oct 11-16

RICE-BRAN OIL TECHNOLOGY [1]

by

Myint Pe
Chemical Engineer, Rangoon, Burma

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United Nations Industrial Development Organization

Interregional Seminar on
the Industrial Processing of Rice

SUMMARY

RICE-BRAN OIL TECHNOLOGY [1]

by

Myint Pe
Chemical Engineer, Rangoon, Burma

I. DEFINITION OF RICE-BRAN

1. Rice-bran is the by-product of rice milling industries. Rice-bran contains essentially the outer portion and germ of the dehulled rice grain. High quality bran is obtained from polishing of rice in the first cone. Rice-bran from second and third polishing contains fines in proportion to the degree of milling. From

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low milling of rice, white bran with 16 per cent to 19 per cent oil content is obtained. High degree milling of rice yields S.Q. Bran with low oil content from 9 per cent to 11 per cent. Milling of parboiled rice yields high quality parboiled bran with 20 per cent to 25 per cent oil content. The quality of bran is classified according to the degree of milling of rice.

II. PROBLEMS IN DEVELOPMENT OF THE INDUSTRY

2. The problems in the development of the industry are discussed in the area of fresh bran supply, the production of a large proportion of industrial grade high acid rice-bran oil from extraction of old bran and the availability of skilled manpower for erection, operation and production management of the plants. The Rice-Bran Extraction Plants require a large quantity of water for cooling and for processing. The quality of water affects the plant, whether it is intended for use in the cooling unit or in the boiler for process steam raising. An industrial water supply should be planned in advance, before any programmes for chemical industries are contemplated in future.

III. PRE-PROCESSING OF RICE-BRAN OIL EXTRACTION TECHNIQUES

3. Pre-treatment of bran prior to extraction of oil is considered as an essential step required for any types of plants either batch or continuous. The reduction of moisture is effected in drying of rice-bran from 12 per cent to 6 per cent. Pelletting on the other hand is to enlarge the particle size of bran to 6 to 8 mm. pellets. Besides a decrease in moisture, pre-treatment (i) reduces fines; (ii) increases particle size; (iii) aides the release of oil from the bran; and (iv) imparts a hardening effect to the bran particles for better extractability, better filtration time and reduction of fines problems.

4. The drying of bran causes the fines to agglomerate which otherwise create problems in the extraction such as channelling effect, resistance or percolation and increase steaming time during desolventization. Rice-bran could be extracted without drying at the expense of inefficiency in extraction rate and high desolventizing time. Pelleting of bran primarily accomplished the enlargement of the particle size. The drying of bran helps promote extraction rate, reduction of fines, increases filtration rate and shortens desolventizing time. Some types of continuous plants used pre-heated bran in place of pelletized bran. As a result, great difficulty is experienced in clarification of fines from the miscella.

5. The rapid formation of free fatty acid is contributed by the action of enzymes which become active and begin to function immediately after the bran is separated from the rice. The reaction may be regarded as the simple oil hydrolysis, catalysed by the lipolytic enzymes in the presence of moisture. The velocity of reaction is fairly high until the moisture content of the bran is controlled to 3 per cent to 4 per cent by heat treatment. The activity of the enzymes is suppressed after heating. The effect of relative humidity was insignificant during storage as the stabilized bran was packed in the moisture-proof bags. The steam-jacketed and insulated dryer could be used as a stabilizer, provided that the incoming bran in the form of thin layer is uniformly heated while transported through the heated wall of the dryer. The inactivation of enzymes in the bran depends on moisture, temperature, and duration of heat treatment. The treated bran should be kept at a fairly constant moisture level. The stabilized bran can be kept for 3 to 4 months in the storage where pest infestation is thoroughly controlled. Pest infestation has caused small perforations in the moisture proof packing. The stabilization techniques has not been commercially adopted. A thorough economic study should be carried out before going into all-out commercial operations.

IV. USES OF RICE-BRAN OIL

6. The refined rice-bran oil is accepted as a good quality cooking oil and is popular dur to its clear, bright yellow colour and its odorless property. As the rice-bran oil is used as an important food item, consistency is quality such as low acidity, colour, flavour, odorless property should be maintained at a certain appropriate standard. As the linolenic acid content is low, the refined oil is very stable, the stability being nearly that of groundnut oil and higher than any other oil. The industrial grade rice-bran oil with high free fatty acid is mainly used as an important raw material for soap industries. The fatty acid hydrogenation plant uses annually 10,000 tons of high acid rice-bran oil and soap stock for splitting, acidulation, high vacuum distillation and hydrogenation. The finished products of varying iodine value are used as a substitute for tallow in the soap industries. Analysis data for crude and refined rice bran oil and its by-products are given for reference.

V. CAPITAL INVESTMENT

7. The total cost of the entire project was recorded as K.35.79 millions (US$ 7.52 m.) for the available extractive capacity of approximately 780 tons raw rice-bran per 24 hours/day. The annual extractive capacity could therefore be estimated as 180,000 to 200,000 tons of raw rice-bran. The installed costs of some types of plants are given in the text. The installed cost of a 25 tons per day batch extraction plant complete with a 6 tons crude rice-bran oil refining unit was US$ 0.34 million as against US$ 0.49 million for a 50 tons continuous extraction plant complete with a 10 tons per day crude rice-bran oil refining unit of continuous design. The installed cost includes cost of equipment, land and plant buildings, cost of erection of the equipment and the auxiliary units.

VI. ECONOMICS OF OPERATION

8. The production statistics for the past ten years are given in the table. The cost of extraction of one ton of raw bran and the cost of refining one ton low acid crude rice-bran oil are given as US$ 10.00 to US$ 11.50 and US$ 11.00 to US$ 16.00 respectively. The cost of chemical for the refinery, which varies with the acidity of the crude rice-bran oil processed, is not included in this cost. The consumption of chemicals increases with the increasing acidity of the crude oil, charged to the refinery.

9. Production of edible rice-bran oil steadily increased from 1961 to 1964. From 1965 to 1967, edible oil production dropped considerably, though total volume of bran fed to the mills for oil extraction did not change significantly. As a result of reviewing the entire rice-bran oil extraction programme, small extraction units of 10 to 15 tons bran per day were added to the existing project. Rice milling plants were programmed in accordance with the requirements of the rice-bran oil extraction plants for maximum supply of freshly milled rice-bran. Integration of rice milling plants with the rice-bran oil extraction programme helped promote the maximum output of edible bran oil. To ensure the supply of freshly milled bran, small extraction plants were erected within the economic radius of the rice mills. The freshly milled bran could therefore be hauled to the bran oil extraction plants, within a few hours.

VII. REVIEW OF THE STATUS OF THE INDUSTRY

10. The performance of the plants are measured in terms of crude oil yield, solvent loss, average acidity of the crude oil charged to the refinery and the yield of edible oil and the by-products. The causes of loss of solvent are discussed and the possible replacement of SBP 62/82°C solvent by a narrow cut solvent like n-hexane is proposed for further exploratory study. Extraction of highly rancid old bran has caused rapid corrosion to pipes and vessels handling high acid crude oil and miscella. The need for research and development work for the rice-bran oil industry, in the area of processing, utilization of wax, deodorizer waste or sludges and the polyunsaturated fatty acid products and the stabilization of bran is emphasized. Technical and economic study of an Integrated Mill Process (SEM) with special reference to the smallest economic unit and its investment cost is recommended for a future programme.

VIII. RECOMMENDATIONS

11. The recommendations made here will serve as a basis for formulating a technical assistance programme needed by the rice-bran oil extraction industry.

12. (i) Fine wax from rice-bran oil should be treated with acetone to remove oil and subsequently recrystalized with Ethyl Alcohol. An exploratory study on the cost of treatment of fine wax, to be used as a substitute for Carnauba wax and others in wax preparations in the pharmaceutical industry should be carried out.

13. (ii) Methods for estimating the isolation of Tocopherol and Oryzanol from unsaponifiable matter of the deodorizer distillate or sludges, and wax from the rice-bran oil industry should be developed.

14. (iii) The quality efficiency rating and the boiling point of the solvents, n-hexane, SBP 62/82°C, and hydrogenated hexane, should be compared. The selection of solvents is to be made on the basis of economic comparison and its acceptability as a food grade solvent which is free from toxicity when left over in oil or in the meal.

15. (iv) The possible use of rice-bran wax as such, or after treatment with acetone, or in hydrogenated form as a raw material for the carbon paper industry, should be explored.

16. (v) A study on the size of the smallest economic unit of the Integrated Milling System (SEM) based on the maximum available supply of paddy in the major rice producing area in the country should be initiated. The study should include on a broad basis, the merits of the Integrated Milling System, cost of investment and benefits compared to the present milling practices with conventional rice mills.

17. (vi) Research and Development in the following area should be undertaken:

18. (a) development of an improved design of condensers and the solvent recovery system in conjunction with the type of solvent usedand the extractive condition of the plants;

19. (b) development of a design of scrubbers to prevent the degradation of Tocopherol in the unsaponifiable matter during the collection of sludges from different types of deodorizing equipment;

20. (c) process research and development on utilization of rice-bran fatty acid for alkyd resins; preparation of an epoxy fatty acid plasticizer as an alternative to soybean oil fatty acids; in the preparation of Dimers from Oleic and Linoleic acid of the rice-bran oil as an alternative to Tallow Oleins for use in rubber plasticizer, foam plystyrene, polyvinylchloride and paint oil; and that of the hydrogenated product of polyunsaturated acids from rice-bran oil for grease making and in tho rubber manufacturing industry.

21. (vii) To establish training facilities, specifically in the area of industrial and chemical technology, production scheduling and control, effective and economic use of utilities such as fuel, power, water, steam, and handling and storage of inflammable chemicals and solvents, particularly directed to the industrial plant safety and prevention of fire hazard, should be made available to production managers, plant supervisors, foremen, process chemists and also plant operators as immediate measures.

For a long-term programme, the Industrial and Chemical Process Technology should be taught at the vocational and the technical high-school level. These programmes, if effectively incorporated, will narrow the technological gap, in many phases of operation and facilitate the operation of the rice-bran oil extraction plants at the optimum level of technology.

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CONTENTS

I. DEFINITION OF RICE-BRAN

1.01. Rice-bran is a by-product of rice milling industries. Rice-bran consists essentially of the outer portion and germ of the dehulled rice grain. Generally two kinds of bran are produced in the milling process. Rice-bran of low food value is obtained from the hulling process in the milling of paddy. The bran produced in the pearling process comprises five thin layers of rice grain consisting of the coat, viz. epicarp mesocarp, cross layers, testa and aleurone layer. Removal of most of these layers is effected in the process of polishing. From high quality milling of rice, low quality bran is obtained. It contains a large percentage of fines so that the oil content of bran is low. High quality bran is obtained from polishing of rice in the first cone. Rice-bran from second and third polishing contains fines in proportion to the degree of milling.

1.02. As an accepted practice in Burma, rice milling is carried out in one continuous stretch, from hulling of paddy to polishing of white rice of any desired quality. From low milling of rice, white bran with 16 to 19 per cent oil is obtained. High degree milling of rice yields S.Q. bran with low oil content, i.e. 9 to 11 per cent. Milling of parboiled rice yields high quality parboiled bran with 20 to 25 per cent oil content. The quality of bran is classified according to the degree of milling. Bran produced in each polishing cone is collected in a single hopper and traded as white or S.Q. bran. White Bran, S.Q. Bran, and parboiled bran are three different types of bran commonly produced in Burma.

1.03. The quantity output of each type of bran varies from year to year, depending on the quality of rice produced for foreign export and local requirements. The method of processing parboiled paddy yields parboiled bran of relatively more stable storage ability, than ordinary rice-bran. The rate of growth of fatty acid in parboiled bran is considerably lower, so that it can be kept for two to three weeks without effecting the quality of the oil in the bran. The presence of large percentage of fines in the different types of bran obtained from the polishing cones, I, II and III, represented here as Grade I, Grade II and Grade III can be noted in the following table.

TABLE (1)

QUALITY OF BRAN FROM DIFFERENT POLISHINGS AND THE PARBOILED BRAN

	Grade I	Grade II	Grade III	Parboiled Bran
Moisture % by wt.	10.9	11.2	11.2	9.9
Crude Protein % by wt.	15.1	16.1	19.1	16.4
Ether extract % by wt.	20.8	17.7	11.5	20.3
Crude Fibre % by wt.	4.8	2.6	0.7	7.3
Total Ash % by wt.	7.1	5.9	4.3	11.6
Acid Insoluble Ash % by wt.	0.8	0.2	0.2	4.4

1.04. As the bran is obtained from the polishing of rice, it may be necessary here to give a description of the rice cone. The rice cone is a standard equipment in every rice mill. In this equipment, the cuticle of rice is removed by means of the revolving action of the cone in the casing, fitted with rubber brakes. The casing is lined with a special steel wirecloth, leaving a narrow annular space surrounding the cone. The cone is usually made of cast iron and mounted on a verticle spindle with the outer surface covered with an artifical dressing of abrasives. The cone rotates at a high speed and the rice is fed in at the top passing down the annular space, between the abrasives surface and the casing fitted with rubber brakes. The milling action is increased by the presence of the rubber brakes in the casing. The resultant bran is propelled through the meshes of the wirecloth and collected in bags. The space between the cone and the casing is adjustable, so that the performance can be varied by raising or lowering the cone. The smaller the space between the cone and the casing, the higher the degree of milling and the greater the resultant quantity of broken rice and bran in relation to head rice. From the existing method of milling, bran is often contaminated with abrasive stone powder. The presence of stone powder in the bran make it unfit for human consumption, though it is rich in protein. The maximum permissible limit for sand and silica in the bran or in the defatted bran is set at 4% by weight for use as animal feed, and poultry farming.

II. PROBLEMS IN DEVELOPMENT OF THE INDUSTRY

2.01. The development of rice-bran oil industry in Burma had its inception in 1957. The first rice-bran oil plant was erected by a local business firm and was partly financed by the Government through an industrial loan. It was designed to extract 40 tons of rice-bran per day and was provided with a refinery for the production of edible oil from low acid rice-bran oil. The equipment and technical services were supplied on a turn-key basis by a reputable foreign firm with good references in the field of rice-bran oil extraction. The technology of rice-bran oil extraction was then at research and development stage in the country. At that time the Union of Burma Applied Research Institute had developed a small solvent extraction unit designed for use in Burmese rice mills. The economic study of the process was carried out in pilot-plant scale. Intensive research programmes on rice-bran and its by-products were carried out in the Institute. Technical services and the training of personnel for quality control were provided for the rice-bran oil industry in the country. The rice-bran oil industry made a steady progress from the period 1957 to 1962. At the end of 1962, 6 rice-bran oil extraction plants were on stream with an extractive capacity of 420 tons rice-bran per day. This rapid expansion in the field of rice-bran oil extraction can be regarded as an establishment of agricultural based industry. The gradual progress in the rice-bran oil extraction technology and the acceptance of products by the public were the result of research and development effort made by the Union of Burma Applied Research Institute in collaboration with the industry concerned.

2.02. The first rice-bran oil plant experienced no difficulty in collection of fresh bran for edible oil production as the bran production far exceeded the extractive capacity of the plant. On the contrary, problems were encountered when all these plants were on stream, with the supply of fresh bran for year-round operation of the plants. The sizes of the plants and their locations determined the availability of fresh bran supply, as these plants were located in the Rangoon area, that the collection and transport on time of fresh bran to these plants was not practically feasible. As an alternative, most of the plants worked on old bran with high acidity. A large inventory of high acid value crude rice-bran oil built up in each plant, so that the prices of the industrial grade high acid bran oil dropped from K.27/00 (US$ 5.67) to K.7/00 (US$ 1.47) per tin of 10 viss (1.63 kg.) within a year in 1963. On the other hand, the colour of the crude oil and softness made it unattractive for soap making. The colour of the high acid crude rice-bran oil influences soap making unfavourably due to its dark brown appearance, attributed to the position and the presence of the conjugated double bonds of the unsaturated fatty acids, which made the bleaching difficult. Most of the soap factories have no facilities for the bleaching of crude oil. Unlike cocoanut oil and the tallow, which are considered as hard fats, the rice-bran oil is classified as soft fats, due to its large content of unsaturated fatty acids. (Oleic and linoleic). The rice-bran oil with the I.V. of 99 to 105 is unattractive as a soap-making component because of its characteristic softness. As the colour and the softness are the principal defects of the high acid crude rice-bran oil, the fatty acid hydrogenation process has to be adopted to produce fat of I.V. 50-60 with the colour comparable to a good grade tallow as a soap-making component.

2.03 The state owned rice-bran oil project was implemented in 1960 with an aim to produce edible rice-bran oil to supplement the country's short supply of edible oil and to utilize the surplus rice bran, which in the past has caused a great burden on account of long and costly storage at high risk of fire to the nearby rice mill and warehouses. The rapid growth of free fatty acid in bran after milling limited the selection of the economic size of the plant and its location. On the basis of available supply of fresh bran in the paddy producing area, 25 tons bran per day extraction plant was assumed as optimum capacity for economic production of edible oil. It followed the same argument that the location of each plant should also be selected in places where rice mills were within the economic radius of the plant and that adequate water supply was readily available.

2.04. The planning of rice-bran oil industries in the state and in the private sector, was carried out by economic consideration only. Technical consideration in connection with the implementation of the project received very little attention. In the course of the execution of the plan, technical problems such as (1) handling and transportation of heavy machinery and equipment to erection sites; (2) training of erection personnel, skilled and unskilled, for erection of the plants; (3) the training of personnel for operation, such as mill hands, operators, supervisors, production managers and engineers for process control, production management and economice use of fuel, power, steam and chemicals for the process were encountered in the course of development of the industry. In fact problems relating to the economic operation of the plant. The importance of process control and quality control could not be readily convinced. With the present outlook, the engineering scale operation of these plants has to be developed for some time.

2.05. The rice-bran oil extraction plants required a considerable quantity of water for cooling and for the processing. Water supply to the plant was considered one of the major problems encountered. The quality of water affected the plant, whether it was intended to be used in the cooling unit or in the boiler for process steam raising. In the dry months, water output from the tube-wells dropped to some extent and the efficient working of cooling, and the spray pond became essential for uninterrupted operation of the plants. In general, industrial water supply problems should be worked out before any industrial programme is contemplated.

III. PRE-PROCESSING OF RICE-BRAN OIL EXTRACTION TECHNIQUE

3.01. Pre-treatment of bran prior to extraction of oil is considered as an essential step required for any type of plant, either batch or continuous. In the batch extraction system, a three-stage dryer was used for pre-treatment of bran to lower the moisture content from 12 per cent to 6 per cent. The dryer is fitted with a rotary paddle conveyor to transport feed material and a steam jacket for heating at a 4 kg./cm^2 steam pressure. Besides a decrease in moisture, pre-treatment (a) reduces the amount of fines; (b) increases the particle size; (c) aids the release of oil from the bran; and (d) imparts a hardening effect to bran particle for better extractability, better filtration time and a reduction of the fines problem. During the drying process, it causes the fines in the bran to agglomerate, which otherwise creates problems in the extraction such as channelling and resistance to percolation and increases steaming time during desolventization. Rice-bran could be extracted without drying at the expense of low extraction rate, high desolventizing time, and high residual oil content. In the rotating extractor, bran is dried to 6 per cent to 8 per cent moisture content by the internally heated coil and the jacketed steam using 8 kg./cm^2 steam pressure, in the extractor itself. The drying time for a 4.5 tons charge of bran is approximately 45 to 60 minutes. Most probably, the pre-heated bran at 90°C to 100°C in the extractor serves as a medium for hot extraction by mixing with low boiling solvent. Pelleting of bran primarily accomplishes the enlargement of the particle size. The drying of bran on the other hand helps promote extraction rate, reduction of fines, increased filtration rate and shortened desolventizing time. Some types of continuous plants use pre-heated bran in place of pelletized bran. As a result, great difficulty is experienced in clarification of fines from the miscella.

3.02. In the continuous extraction plants, pre-processing of bran is carried out in a different way. The bran is fed to the pelletizing equipment to enlarge the particle size of the bran to 6 - 8 mm. pellets. This is the most costly method of treating bran prior to extraction as it required a sizeable quantity of electricity per ton of bran processed to pellets. Pelletizing of bran before charging to the extraction system is a basic requirement for some types of continuous extraction plant. The pelletizing of bran not only reduced the moisture content of the bran, but also helped to eliminate the fines.

3.03. To prevent a rapid growth of free fatty acid, rice-bran requires heat treatment immediately after it comes out from the rice mill. Pilot plant study on heat stabilization of bran was made with a 5 tons per day stabilization plant, which was installed in the rice mill. The incoming fresh bran transported in the form of a thin layer through the steam heated wall results in every particle of bran being heated uniformly at the specified condition. The temperature of the bran at the outlet of the unit should not exceed 110°C and the rate of transport of bran from inlet hopper to the outlet varied from 90 to 120 minutes. The final moisture content of the heat-treated bran was about 4 per cent. The stabilized bran was then cooled down to about 80°C and packed in moisture-proof bags. The rapid formation of free fatty acid is attributed to the presence in the bran of enzymes which become active and begin to function immediately after the bran is separated from the rice. Growth of free fatty acid in the bran is presumably caused by the simple oil hydrolysis catalysed by the lipolytic enzymes in the presence of moisture in the bran. The velocity of reaction is fairly high until the moisture content of the bran is controlled at around 3 to 4 per cent, by heat treatment. The activity of the enzymes is totally suppressed after heating. The effect of relative humidity was insignificant during storage as the stabilized bran was packed in the moisture-proof bags. It is also important that the treated bran should be kept at fairly constant moisture level. The stabilised bran can be kept for three to four months in the storage where pest infestation is thoroughly controlled. Pest infestation has caused small performations in the moisture-proof bags. The moisture content of the bran therefore gradually rose to a point till equilibrium was reached. The steam-jacketed and well-insulated dryer fitted with a paddle or a screw conveyor could be used for stabilization of bran, provided that the rate of transport of fresh bran from inlet to the outlet hopper is about 90 to 120 minutes. The length of the dryer and the speed of the conveyor are designed in such a way that the bran particles get sufficiently heated during transportation, inside the dryer. The stabilization technique has not yet been commercially adopted. The cost of treatment of bran, selection of moisture proof packings, and the problems involving cost and the optimum economic size of the stabilizer unit, such as whether small units are to be attached to every rice mill or larger centralized plants are to be installed require thorough economic study before going into all-out commercial operation.

3.04. As the rice-bran oil extraction plants and the refinery units attached were of different types and design an evaluation of the different extraction and refining techniques for rice-bran oil would be invaluable. The extraction techniques for three different processes, viz. batch filtration-extraction, rotary batch, and the continuous and the evaluation of different refining processes are described in the following pages.

3.05. (a) In the batch filtration extraction system, drying of bran is separately done in a three-stage dryer, by jacketed steam heating. The treated bran at 6 per cent to 8 per cent moisture is charged to the extraction vessels each holding 0.4 tons of raw bran. This system consists of five stationery extraction vessels. Thick sugar-bag twill sacking fitted on the false bottom of the extraction vessel serves as a filter. Solvent is pumped around the vessel, ensuring maximum usage of solvent circulation. After extraction, steam at 2 atmosphere is applied to force out miscella to the miscella tank. The miscella from the extractor passes through a strainer. The bottom steam is used to drive off solvent out of meal. Hot vapour is effectively used for pre-heating of miscella in the heat exchanger. Last traces of solvent in the oil are removed in the final stripper. Meal with a residual oil content of 2 - 3 per cent, moisture content of 8 - 12 per cent is discharged from extractor by opening the door of the extraction vessel and by raking out, conveyed to the next building by screw conveyor and crushed to powder and bagged off. Based on 2½-hour cycles per batch the capacity of the plant for 24 hours is 25 tons. This system is preferred over the rotary batch extraction as the maximum usage of solvent is obtained by several pass percolations by a gear pump, thereby reducing the solvent to meal ratio required for extraction.

(b) In the rotary batch extractor system, the plant consists of three rotary extractor each with a capacity of 4.5 tons raw bran per batch Bran is charged and dried to 6 - 8 per cent moisture content in the extractor itself. The extractor is fitted with a solvent. Th material is thoroughly mixed with the solvent by the rotation of the extractor during the process of extraction. The miscella is then removed and filtered in a built-in filter basket. Subsequently the miscella is subjected to a second and a third filtration. The clear miscella is distilled in two stages. Pre-distillation removes a major portion of solvent from the miscella under normal pressure. The equipment uses the principle of thin film evaporation. The solvent vapours are condensed in the recovery condensers. The miscella, rich in oil from the pre-distillation unit, is fed to the distillati n vessel for final distillation. The last traces of solvent are removed in high vacuum and by blowing in direct steam. When the last charge of solvent has been drawn off as miscella from th extractor, solvent is removed from the extracted meal by heating with indirect steam in the extractor. Last traces of solvent are eliminated by means of direct steam when the extractor is under vacuum. Rotation of the extractor and the vacuum avoids an over heating of the meal being desolventized. Dust particles in the solvent vapour are eliminated by the direct filter and the cyclone. The clean solvent vapours are recovered in the condensing system. Although the bran is extracted one batch after another, the principal design feature is not similar in any way to the stationary batch filtration extraction system. The rotary batch extraction requires multistage filtration equipment for clarification of miscella. To get minimum residual oil content at least, two to three washes of solvents are needed. Thus the solvent to meal ration is high compared to the other system.

(c) Continuous system consists of two identical extractors each containing one continuous unit capable of 25 tons raw bran in 24 hours is provided with continuous meal desolventizer, miscella evaporator and fines filter. Dry bran is fed in at one end continuously. At the other end solvent is pumped in continuously, thus operating a counter flow to the passage of the meal through the extractor. Bran falls into the first of a series of seven small elevators installed at an angle, each elevator being driven by geared motor. To each elevator is fastened a series of metal mesh buckets. The first buckets received the charge of fresh bran. The lower half of the elevator is immersed in solvent. The meal out of No. 1 bucket is discharged and passed into the next section No. 2 to 3 to 4 up to 7. Clean solvent comes in at the other end and passes in counter flow along the No. 7 section to No. 1 section and then comes out of the extractor overflow to the miscella receiving tank. The miscella passes to a high speed fines separator called Superdecanter running at 3,250 rpm. The fines remain in a mesh casing inside and the liquid passes through the fines discharged at the end mixed with 18 - 20 per cent oil, worked back into a tank below and pass to the distillation vessel, each vessel alternately running for about 8 hours. Final tests on oil are made by smell and laboratory drying. Meal from the extractor is desolventized in a three stage dryer and passed through a water cooled conveyor and bagged off. Hot vapour from the meal dryer is passed through a fines scrubber and condenses in the shell and tube type condensing unit. The continuous rice-bran extraction plant differs from average solvent extraction technology and equipment in the following area: (a) transport of solvent rich meal from the extractor to the meal desolventizer requires specialized equipment; (b) clarification of fine rich miscella need special technology and equipment for effective removal of fines; (c) solvent to meal ratio can be adjusted to the desired level of residual oil content in the meal, and (d) some types of continuous rice-bran extraction plants are still facing the problem with fines in the vapour phase and in the liquid phase.

3.06. Evaluation of extraction processes: in the batch and the rotary batch plants, solvent to meal ratio is important for keeping residual oil in the meal down to a minimum. In continuous plant, counterflow of meal and solvent is designed in such a way that solvent to meal flow could be adjusted to optimum. For separation of fines in miscella, each plant solves the problem in its own way. No single plant produces fines-free crude rice-bran oil. The vacuum drum filter has not been used for separation of fines. All possible efforts have been made to work in this direction. Pelletizing of bran helped minimize the fines in the miscella, but the results are still far from satisfactory. The filtration system used in the rotary batch plant poses a problem of explosion. Solvent laden meal has to be taken out quite often into the open, when filter bags need cleaning and replacement. It is injurious to the health of the personnel who actually handled solvent-laden meal during operation. The constructional material used in the batch plants are not suited for service, handling of high free fatty acid oil. The corrosion rate is considerably high in these plants. Vapour phase fines scrubbers were installed in some plants to improve heat transfer in heat exchangers and coolers. Additional units for condensing of solvent vapour were designed, fabricated and installed in most of the plants to improve recovery of solvent. Though sulphur in the solvent was not detectable in fresh charge, cumulative effect of sulphur causes severe corrosion, along the vent pipe of the recovery system in batch plants, it may be probably due to the concentration of sulphur in solvent when low boiling fractions escaped during operation were on constant refilling with fresh charge.

3.07. Evaluation of refining process: each rice-bran oil plant has its own design of alkali refining unit and deodorizing system. In one process, crude oil is charged to batch neutralizer fitted with agitator. The resultant oil and soap stocks are separated in a continuous centrifugal separator. The neutral oil is fed to the bleaching vessel and then to high vacuum tray deodorizer for removal of traces of fatty acid and odorous matter. The deodorized oil is cooled to room temperature and filtered in bags. In another process, short-mix continuous neutralizer unit consisting of a plate heater, a proportioning mixer and a soap stock separator for complete removal of free fatty acid. The neutralized oil is then fed to a bleaching vessel, operating under vacuum and the bleached oil is charged to a batch deodorizer working under high vacuum. In this unit the deodorized oil is cooled down to 15°C by jet vacuum cooling system and dewaxed in a large plate and frame filter press. In some plants a gravity separation is employed for soap stock separation, coupled with bleaching under vacuum. A continuous vacuum deodorizer unit is also used here. Dewaxing technique consists in cooling the oil to about 15°C and keeping it at that temperature for about 24 hours and then filtering it with a very large filtering surface, so that the maximum pressure developed in the filter press is around 0.5 kg./cm.^{2} Some plants use a series of gravity filter bags made of duck cloth or canvas for dewaxing at room temperature. The cooling of oil to 15°C is carried out in a tank provided with a cooling coil for chilled water circulation cooling and a stirring mechanism which steadily moves the oil to be cooled. The water for circulation is cooled down by a steam jet refrigerator to about 10°C to 12°C to subsequently cool the oil. When the temperature of the oil is about 15°C it is pumped into a filter press. The wax retained in the filter surface is collected. Final dewaxing as described above is carried out, after the oil has been duly deodorized.

3.08. Production of high vacuum required for deodorization of rice oil can be seen in different plants as follows: (1) uses of multistage steam ejectors; (2) use of mechanical vacuum pump coupled with a single stage booster, and (3) use of a large mechanical vacuum pump. The short-mix continuous neutralization unit gives a good colour oil, free from residual sodium soap content and free fatty acid with low refining losses. The refining factor, recorded in this plant, is as low as 1.6 for an average acidity of 20 per cent FFA. The multistage vacuum system for deodorization is so effective that deodorization can be carried out at a fairly low temperature, so that the steam pressure required is in the order of 175 to 180 psig., for heating of oil during deodorization. This plant, simple to operate, is technically the most efficient compared to others. A tray type deodoriser unit fitted with an automatic control panel for charging and discharging of oil under high vacuum is also used for deodorization. Downtherm liquid is used as a heat transfer medium in a closed circuit heating system. The continuous column deodorization unit does not work as efficiently as expected as the vacuum produced by a large single mechanical vacuum pump is not sufficient for the service. The edible oil produced in this plant contains traces of odorous matter and the colour, unacceptable to the consumers, due to prolonged heating of oil under insufficient vacuum. Every effort is being made to improve the performance of each equipment in the plants.

IV. USES OF RICE-BRAN OIL

4.01. From freshly milled bran, low acid refinable crude rice-bran oils of AV 30-40 were produced. From stored bran, high acid value industrial grade oil was obtained. Freshly milled rice-bran here means bran with a storage life of one to two weeks for white and S.Q. bran. For parboiled bran, storage life can be extended to one month without seriously affecting the acidity in the oil. Low acid value oil could be easily refined in the conventional refining equipment and gives good quality edible oil with some valuable by-products. The yield of edible oil depends on the acidity of the feed material. With the modern continuous centrifugal separation technique, refining factor for the average acidity handled is in the range 1.6 to 1.9. In the batch process refining factor recorded was around 2 or a little over 2 on neutralization.

4.02. Rice-bran edible oil is used as cooking oil. Since its introduction to the public in Burma in 1961, edible rice-bran oil is readily accepted as good quality oil, especially for frying. The consumers' response to the edible rice-bran oil is quite favourable. The odourless properties of oil and its clear, transparent, bright yellow colour was popularly recognized in the market as fully refined edible oil. Despite readily available supply of G/N and sesame oil, used for years as unrefined edible oil, rice-bran oil is preferred for its low acidity, colour and the odourless property. The quality of refined oil is readily recognized by its non-forming property in frying. As the rice-bran oil is used as an important food item, it is extremely important to see that quality consistency, low acidity, clear, transparent, bright yellow colour, flavour and the odourless properties should be maintained at a certain appropriate standard, which is practicable to the conditions of the existing refinery plants.

4.03. Composition of fatty acids in the rice-bran oil: as examination of rice-bran oil of Burmese origin gave the following result -

±	18%	Palmitic Acid
±	1%	Linolenic Acid
±	35%	Linoleic Acid
±	40%	Oleic Acid
±	3%	Stearic Acid
±	3%	C_{20} - C_{24} Saturated Acids

The average value of linoleic acid found in the literature is, in any case, more than 30%. As the linolenic acid content is quite low, the refined oil is very stable, the stability being nearly that of G/N oil and higher than that of the normal oil. Due to its high linoleic acid content (essential fatty acid) it is a very good oil for edible purposes.

TABLE (2)

SPECIFICATION FOR CRUDE AND REFINED RICE-BRAN OIL

Characteristic		Crude Oil	Refined Oil
Moisture and insoluble Impurities %		8.76	0.05
Colour in ½" cell on Livibond scale expressed as Y-5R not deeper than	R	4.40	R 1.30
	Y	38.10	Y 3.80
	B	2.30	B 0.80
Refractive Index at 40°C		1.4638	1.4638
Specific Gravity at 30/30°C		0.9104	0.9120
Saponification value		201	185
Iodine value (Wij.)		99	100
Acid value		14.55	0.23
Unsaponifiable matter, % by wt.		2.60	3.27
Flash point, Pensky Martins (closed) °C		343	343

4.04 High acid rice-bran oil was primarily used as raw material for soap industries. For some years, the quantity of high acid rice-bran oil used in soap industries was insignificant. It was probably due to the problems associated with it, namely, dark colour and softness. With improved technology in the soap manufacturing process, high free fatty acid rice-bran oil of industrial grade became a good starting material for soap industry. To narrow the technological gap in the utilisation of high acid crude rice-bran oil, a 40 tons per day fatty acid hydrogenating plant was built for fat splitting, high vacuum distillation and hydrogenation of distilled fatty acids. This facilitates utilisation of high acid rice-bran oil to produce polyunsaturated fatty acid of quality. If fatty acid product of high melting point were needed, polyunsaturated acid could be further hydrogenated. The finished product of Iodine value 5 can be a good substitute for stearic acid.

4.05. Soap Stock - the chief by-product of the refining process is also an important raw material for soap making. Some manufacturersused soap stock as a basis material for low grade soap powder for household use. Acidulation of soap stock eliminates water and gives acid oil. Soap stock or acid oil was used as a starting material for processing of polyunsaturated fatty acid and its hydrogenated derivatives.

4.06. From rice-bran two types of wax were produced. One from pre-filtration of crude oil is called crude wax and impurities. Final dewaxing operation produces a good quality wax. Wax obtained from both operations contains a certain amount of free oil in it. Rice-bran wax is rich in unsaponifiable matter. The crude wax and impurities are used in the soap industries as the principal raw materials. Fine wax from final dewaxing of deodorized oil usually contains 50% oil. The rice wax is separated from the oil by precipitating with acetone, as it is insoluble in acetone. The precipitate of wax is recrystallized by use of ethyl alcohol. In some processes, the solution of wax in acetone is cooled to 10°C and kept overnight and centrifuged. The recovered wax is again mixed with cooled acetone and centrifuged to remove the last traces of oil. The traces of solvent are removed by heating the wax at 60°C to 65°C. Wax is then boiled for a short time in 1% solution of sulphuric acid. Wax floats on the surface. Non-waxy impurities such as foots remain at the bottom. After cooling the solution, solid wax is separated and dried. It is therefore recommended that the rice-bran oil wax be refined in acetone and recovered as described above, and to explore the possible use as such, fractionated or hardened, to replace Carnauva wax and others in wax preparations in the pharmaceutical industry.

TABLE (3)

ANALYSIS DATA FOR RICE-BRAN OIL WAX AND SLUDGES

	Wax I	Sludges I	Wax II	Sludges II	Fine Wax	Sludges III
Ash%	0.3	43.8	0.3	2.1	1.7	0.8
Moisture%	0.1	8.2	3.6	44.3	2.0	5.4
FFA%	3.9	18.2	34.1	43.6	5.6	21.7
Unsap. Matter%	15.2	4.8	9.5	5.6	9.3	7.3
Sap. value	138	200	197	108	167	163
Iodine value	53	29	73	45	75	77
*Vitamin %	0.09	-	-	0.045	-	-

* Expressed as a tocophryl acetate.

4.07. High vacuum deodorization of bleached oil gives sludges or deodorizer waste collected from the barometric leg of the deodorizer unit. These sludges were also obtained as a by-product from high vacuum distillation of fatty acids. The unsaponifiable matter of the deodorizer distillate or sludges and waxes contain specifically the stigmasterol portion of sterol and tocopherol. Soybean oil sludge is richest in stigmasterol and tocopherol. To prevent degradation of tocopherol in sludges, a good collection system is needed. To increase recovery of distillate from the condensers, installation of condensate scrubbers may be needed for improved sludge quality. Further research in unsaponifiable matter of the sludges and waxes from rice-bran oil industries should be conducted in the area of estimation and isolation of tocopherol and oryzanol.

V. CAPITAL INVESTMENT

5.01. The official exchange rate for kyats equivalent of US$ is given as K.100/00 equal to US$ 21.00. Out of 6 rice-bran oil extraction plants in the private sector 4 plants were built with refining facilities for production of edible oil. Total capacity of these plants is 420 tons of raw bran per day. Capital investment for these plants represents K.16.5 millions(US$ 3.47 million). The cost of machinery and equipment was K.10.7 millions (US$ 2.25 million), with foreign exchange (F.E.) component of the plants estimated as K.9.87 millions (US$ 2.07 million). In the state sector, (1) the capital investment for the first project, consisting of ten rice-bran extraction plants cost K.17.13 millions (US$ 3.60 million). The machinery and equipment represents K.8.5 millions (with the F.E. component estimated as US$ 1.78 millions; (2) the extension project comprising 6 small extraction plants, each having the capacity of 10 to 15 tons per day of rice-bran cost K.1.07 millions (US$ 0.22 million), for the total capacity of 85 tons per day raw rice-bran. As these plants were designed and fabricated locally, the direct F.E. component was as low as 10 to 15 per cent.

5.02. The total capital cost of the entire programme amounted to K.35.79 millions for 22 extraction plants with the total extractive capacity of 780 tons of raw rice-bran per day. The F.E. cost of the projects was K.17.98 millions (US$ 3.8 m.). In the programme there were 16 batch extraction plants of different designs and makes, 3 continuous plants of different designs and 6 rotary batch plants of the same make and design. Refinery units attached to these plants were of a different design altogether. It is therefore extremely difficult to compare the capital cost of these plants. In the following table, some illustration on the capital investment of each plant by type are listed:

TABLE (4)

INSTALLED COST OF RICE BRAN OIL EXTRACTION BY TYPE

	Capacity Tons	Total Installed Cost (Kyats)	Total Installed Cost (U.S.$)
Batch extraction with Batch refinery Unit	20	1,616,155	340,245
Rotary batch extraction and batch refinery unit	25	1,893,407	399,776
Continuous extraction and continuous refinery unit	50	1,918,077	408,806
Continuous extraction Unit only	60	2,433,705	532,000

5.03. Total installed cost of plant includes cost of equipment, cost of land and buildings and cost of erection of the plant and auxiliary equipments. The extractive capacity of the plants in the private sector ranges from 45 tons per day to 85 tons per day of raw bran. In the state sector, the capacity of the plant ranges from 10 tons to 50 tons per day of raw bran.

VI. ECONOMICS OF OPERATION

6.01. The annual production of bran in Burma can be estimated as 180,000 to 200,000 tons obtained from milling of rice by the state. Milling of rice by farmers for home consumption were not accounted for, as the quantity milled at any one time was insignificant, and the collection difficult. In fact, the farmers get the bran back from the local rice mill and use it up for cattle and poultry food on the farm. Bran in the upcountry representing about 20% of the total production could not be realised as the cost of transportation will be high and uneconomical. Some 15 per cent were issued yearly for poultry and cattle feed, to the deficit area in the country. When feed meal industries were developed and defatted bran utilized efficiently, old practices of feeding raw bran in bulk to cattle and poultry could be replaced by more scientific compound feeding method. Raw bran will then be available for oil extraction. Estimation of the supply of rice-bran for foil extraction requires some knowledge in the pattern of procurement, processing and handling of paddy in the country. If the total quantity of paddy produced in the country was used as a basis for estimation of bran supply, it would far exceed the actual quantity of bran available annually in Burma for oil extraction.

6. 02. Production of edible rice-bran oil was steadily increased from 1961 to 1964. From 1965 to 1967, edible oil production dropped considerably although total volume of bran fed to the mills for oil extraction was not changed significantly. During that period, the rice-bran extraction programme was reviewed thoroughly and the extension programme worked out. As a result, 6 new rice-bran extraction units locally designed and fabricated with capacity ranging from 1o to 15 tons per day were added to the existing project. Rice milling plans were regulated and programmed in accordance with the requirement of the rice-bran oil extraction plants for maximum supply of freshly milled rice-bran. Integration of rice milling plants with the rice-bran oil extraction programme helps promote the maximum output of edible bran oil. Transportation of bran to the bran oil plants were planned in advance. Intensive inspection methods were employed for efficient operation. With the result, the edible rice-bran oil output increased in 1968/69. To ensure the supply of freshly milled bran, small 10 to 15 tons units were erected within the economic radius of the rice mills. Rice-bran was produced in abundant supply and the freshly milled bran could then be hauled to the bran oil extraction plants within a few hours.

6.03. From rice oil extraction, 80 to 82 per cent of defatted bran and 14 per cent crude bran oil were produced with a process loss of 6 per cent. Recovery of edible oil from the refining operation depends on the acidity of crude oil refined. The average acidity of crude oil processed in the refineries ranges from AV 20 to AV 40. The yield of soap stock is twice the fatty acid in the crude oil.

TABLE (5)

ANNUAL PRODUCTION OF RICE-BRAN OIL AND BY-PRODUCTS

Year	Raw Bran Processed	Defatted Bran	Edible Oil	Industrial Oil
1959/60	21,376	17,101	449	1,179
1960/61	42,753	34,202	898	2,394
1961/62	81,267	65,014	3,413	5,689
1962/63	89,323	71,458	3,751	6,253
1963/64	87,503	69,580	3,675	6,125
1964/65	109,257	88,483	952	10,525
1965/66	82,284	68,654	621	8,169
1966/67	79,146	66,094	882	7,276
1967/68	50,707	42,778	726	4,242
1968/69	63,778	52,793	2,834	2,347

Expressed in metric tons

6.04. Extraction costs for one ton of bran processed in different type of extraction plant were represented here as a good basis for evaluation of the performances of the plants. Plant A, for rotary batch type, Plant B, for batch filtration-extraction type and the plant C, for continuous type, chosen for comparison of performances and the manufacturing costs by the significant cost centre.

TABLE (6)

EXTRACTION COST FOR ONE TON OF BRAN PROCESSED IN DIFFERENT PLANTS

		PLANT A Kyat	PLANT A %	PLANT B Kyat	PLANT B %	PLANT C Kyat	PLANT C %
1.	Direct Labour	4.3	77.8	9.6	18.5	4.5	9.1
	a. Salary			6.9			
	b. Overtime			0.7			
	c. Wages			2.0			
2.	Varial Exp.	28.0	51.5	23.7	45.5	22.4	45.8
	a. Solvent	21.3		16.6		6.9	
	b. Fuel	4.7		5.1		10.3	
	c. Power	1.8		1.8		5.1	
	d. Lubricant	0.3		0.2		0.1	
3.	Fixed Exp.	18.7	34.5	15.0	28.9	21.1	43.1
	a. Depreciation	11.9		6.5		13.4	
	b. Maintenance	2.3		2.6		1.0	
	c. Social Security	0.6		2.3		0.3	
	d. Insurance	0.8		1.2		1.5	
	e. Others	3.1		2.4		4.9	
4.	Administrative Overhead	3.4	6.2	3.6	7.1	0.9	2.0
	Total Cost	54.4	100	51.9	100	48.9	100
	Milling Tons	10,288		17,407		12,716	
	Period	9 mos.		9 mos.		9 mos.	

TABLE 6 (a)

EXTRACTION COST FOR ONE TON OF BRAN PROCESSED IN DIFFERENT PLANTS

(Equivalent US$ Cost)

		PLANT A US$	PLANT A %	PLANT B US$	PLANT B %	PLANT C US$	PLANT C %
1.	**Direct Labour**	0.90	7.8	2.02	18.5	0.95	9.1
	a. Salary			1.45			
	b. Overtime			0.15			
	c. Wages			0.42			
2.	**Variable Exp.**	5.89	51.5	4.98	45.5	4.70	45.8
	a. Solvent	4.47		3.49		1.45	
	b. Fuel	0.98		1.07		2.16	
	c. Power	0.38		0.38		1.07	
	d. Lubricant	0.06		0.04		0.02	
3.	**Fixed Exp.**	3.93	34.5	3.15	28.9	4.43	43.1
	a. Depreciation	2.50		1.37		2.81	
	b. Maintenance	0.48		0.55		0.21	
	c. Social Security	0.13		0.48		0.06	
	d. Insurance	0.17		0.25		0.32	
	e. Others	0.65		0.50		1.03	
4.	**Administrative Overhead**	0.71	6.2	0.75	7.1	0.18	2.00
	Total Cost	11.43	100	10.90	10C	10.26	100
	Milling Tons	10,288		17,407		12,716	
	Period	9 mos.		9 mos.		9 mos.	

6.05. Direct Labour Charges was K 4.3 for the plant A, as compared to K 9.6 for plant B, and K 4.5 for plant C. The plant B representing stationary batch type of old design required more labour than the other two plants. Solvent loss in plant A was K 21.3 and in plant B K 16.6 as against K 6.9 in plant C, for the period under study. It shows that the solvent recovery system works well in plant C which is the continuous type f modern design. Fuel charges per ton of bran processed in plant A shows the lowest, which is K 4.7 as compared to K 5.1 in plant B, and K 10.3 in plant C. High cost in fuel was affected by the use of fuel oil in plant C. Plants A and B use sawdust and rice husk as boiler fuel for steam raising. Electric power consumption was high for the continuous plant C, and comparatively low for batch plants. Depreciation per ton of bran processed for plant C was K 13.4 as against K 11.9 for plant A and K 6.5 for plant B. High capital cost for the continuous plant was responsible for the high depreciation costs over the other plants.

6.06. Refining charges for one ton of crude rice-bran oil processed in different type of refining units are reported here as an indicator for economic of production of rice-bran oil. The cost of chemical for the refinery, which varies with the acidity of the crude rice-bran oil processed, was not included in this cost. The consumption of chemical increases with increasing acidity of the bran oil charged to the refinery. The first two plants D and E were fitted with a continuous neutralization unit coupled with batch bleaching and deodorization unit. The plant F represents the batch design unit for neutralization and bleaching with modern semi-automatic high vacuum deodorizer unit. Here again, batch plants required more labour than the continuous one. The process loss on refining is high in the batch plant as compared to the continuous plant of modern design, for the same acidity of crude bran oil refined. Since the initial costs of the continuous plants were much higher than the batch plants, depreciation charges were much higher per ton of crude oil charged. The refining charges are reported in the foregoing pages for review.

6.07. The chief objective for extracting oil from raw rice-bran was to alleviate the shortage of edible oil in the country. As a major by-product, defatted bran meal was produced. From the total oil production, the yield of edible oil ranges from 25 to 55 per cent while soap stock, the major by-product of the refining process, was about 50 to 60 per cent on the total fat basis. It should be noted that edible rice-bran oil sells for four times the price of industrial grade rice-bran oil. Though the rice-bran oil extraction plants relatively produced more industrial crude oil than edible rice-bran oil, the investment for these plants was paid off in a few years. It was mainly due to (1) difference in prices between raw rice-bran and defatted bran, as major proceeds were collected from export of defatted bran, and (2) the industrial crude oil used for soap industries set off the quantity of tallow, imported from abroad.

6.08. Though there were no serious problems involving storage of bran and the defatted bran, adequate storage space needs to be provided in rice-bran oil extraction plants, to avoid frequent shut down due to congestion of produots. Transportation of by-products should be planned in accordance with the needs of these plants. In practice, raw rice-bran and defatted bran, to and from the plants, were transported by trucks, river craft and railway. Rice-bran gets rancid very rapidly after milling, and any delay in transportation means allowing the acidity of the bran to rise beyond refinability. To promote edible oil production in each plant, oolleotion of fresh bran was organized in accordance with the oapacity of each plant. Rioe milling plants were integrated with the rice-bran oil extraction programme, and as a result, fresh bran could be hauled to the bran oil extraction plants in time, with available transport facilities. Efficiency as against oost of transportation should be properly controlled. So far, progress in this direction is gaining momentum.

6.09. To lower the cost of production in the plants, process control and subsequent oost control data should be introduced, so that the efficiency of each plant oould be asoertained and appropriate costing issued. To achieve this, process or produotion control staff suoh as a production manager for each mill should be trained in prooess and oost oontrol, organization and management, labour relations and oontrol.

TABLE (7)

REFINING COST FOR ONE TON OF CRUDE RICE-BRAN OIL

	PLANT C Kyats	PLANT C %	PLANT D Kyats	PLANT D %	PLANT E Kyats	PLANT E %
1. **Direct Labour**	13.9	26.0	10.4	15.4	33.8	43.4
a. Salary					27.7	
b. Overtime					1.2	
c. Wages					4.9	
2. **Variable Exp.**	8.8	16.7	10.5	15.5	8.8	11.3
a. Fuel	6.5	5.1	5.1		5.5	
b. Power	1.7		4.5		2.9	
c. Lubricant	0.6		0.6		0.4	
d. Others	-		0.3		-	
3. **Fixed Exp.**	27.7	52.2	38.1	56.6	29.2	37.5
a. Depreciation	20.2		25.6		17.1	
b. Maintenance	0.5		1.1		5.0	
c. Social Security	3.4		1.3		2.2	
d. Insurance	2.8		2.1		0.6	
e. Others	0.8		8.0		4.3	
4. **Administrative Overhead**	2.7	5.1	8.5	12.5	6.1	7.8
Total Cost	53.1	100	67.5	100	77.9	100
Milling Tons	573		1826		1950	
Period	4½ mos.		9 mos.		9 mos.	

TABLE 7 (a)

REFINING COST FOR ONE TON OF CRUDE RICE-BRAN OIL
(Equivalent US$ Cost)

		PLANT C US$	PLANT C %	PLANT D US$	PLANT D %	PLANT E US$	PLANT E %
1.	Direct Labour	2.92	26.0	2.18	15.4	7.10	43.4
	a. Salary					5.82	
	b. Overtime					0.25	
	c. Wages					1.03	
2.	Variable Exp.	1.85	16.7	2.20	15.5	1.85	11.3
	a. Fuel	1.36		1.07		1.16	
	b. Power	0.36		0.95		0.61	
	c. Lubricant	0.13		0.12		0.08	
	d. Others	-		0.06		-	
3.	Fixed Exp.	5.82	52.2	8.00	56.6	6.13	37.5
	a. Depreciation	4.24		5.38		3.59	
	b. Maintenance	0.11		0.23		1.05	
	c. Social Security	0.71		0.27		0.46	
	d. Insurance	0.59		0.44		0.13	
	e. Others	0.17		1.68		0.90	
4.	Administrative Overhead	0.56	5.1	1.79	12.5	1.28	7.8
	Total Cost	11.15	100	14.17	100	16.36	100
	Milling Tons	573		1826		1950	
	Period	4½ mos.		9 mos.		9 mos.	

VII. REVIEW OF THE STATUS OF THE INDUSTRIES

7.01. Up to 1967, rice-bran oil extraction plants were working in full capacity, utilizing fresh bran available in the rice milling season and supplemented with old bran for year round operation. As a result, the edible oil and the industrial crude oil were produced. Sometime in 1968, integration of a rice milling plant with a rice-bran oil extraction programme was introduced, and the plants were operating on fresh bran only. To achieve the planned output of edible rice-bran oil, extraction of old rice-bran was discouraged. Because of an intensive inspection programme adopted for supply of fresh bran to the plants, the rice-bran oil extraction project received maximum attention at all levels of management. The fresh bran supply was not adequate; despite every possible effort made for improvement, the extraction plants ran hardly two shifts a day. In 1969, the old practice was revived, as industrial grade rice-bran oil was needed for the soap industries. The extraction plants were again running on full three shifts for year round operation.

7.02. Despite the main objective of rice-bran oil extraction being to step up edible oil production in the country, industrial rice-bran oil was required for the country's soap industries. The fatty acid hydrogenation plant needs annually over 10,000 tons of high acid value crude rice-bran oil and soap stock. Hydrogenation fatty acid products find many uses in soap, paint, greases and in rubber industries.

7.03. Some data on yield, solvent loss, and average acidity of crude rice-bran oil are mentioned here in the following pages for evaluation of performance of the plants. High losses of solvent consist in storage losses and loss during operation. Factors contributing to loss of solvent in operation are as follows: (a) solvent left over in extracted meal; (b) solvent left over in crude oil; (c) solvent loss through vent as uncondensable vapour, and (d) solvent loss due to careless handling of control devices by plant operators. Proper maintenance of extractor and the distillation vessel is also important. Traces of solvent left over in meal as well as in the crude oil are quite common in the batch and the rotary batch system. Fines in the bran channel out, when expelling solvent in the batch extractors so that heat flow through the meal bed is unevenly distributed. Leakages of solvent or miscella from pumps, glands and joints are significant. Storage of solvent in drums causes loss of solvent up to 10% if the packing, mode of handling and storage are not in proper condition. The specification of solvent SBP 62/82°C currently used for extraction may be one of the factors contributing to high loss of solvent. It required at least 4 to 6 kg./cm^2 of steam pressure to be applied for complete removal of solvent in meals. For distillation heating to 100 to 120°C is needed for removal of solvent. This is probably due to the wide range of boiling point in SBP 62/82°C cut solvent. If narrow cut solvent like n-hexane were used for extraction, it could have saved some solvent as the narrow boiling range of n-hexane results in easier and more efficient recovery from the extracted bran and crude oil. Furthermore, plant efficiency could be increased by the ease in achieving true equilium when solvent with a narrow boiling range is used. A narrow cut solvent like n-hexane can be removed from the meal and the miscella at a lower temperature than SBP 62/82°C solvent. Steam requirement should therefore be reduced and lower temperature also means less protein coagulation.

TABLE 8

SPECIFICATION OF SOLVENT SBP 62/82°C AND N-HEXANE

		SBP 62/82°C+	n-HEXANE ++
Specific gravity 60/60°F		0.6805	0.665
Distillation ASTM D-86, IBP°C		64.0	68.8
90% recovered, °C		67.5	-
FBP °C		74.0	-
Colour ASTM D-156		+ 30	+ 30
Doctor test		- ve	- ve
Aromatic % vol.		3	0.0005(gm/100ml)
Lead, ppm (W/V)	Less than -	0.2	-

+ Shell's SBP 62/82°C

++ Philip's petroleum, n-HEXANE

7.04. The price of the n-hexane is the dominant factor in substituting SBP 62/82°C for n-hexane. The rice-bran oil industry is the first of its kind in the country utilizing industrial solvent and the problems pertaining to its use should be solved in the course of time. Extraction solvent boils over a range depending on the boiling point of the individual component. To minimize solvent loss, this boiling range should be as narrow as possible. If a high proportion of low boiling materials is in the solvent, high losses can be obtained during processing. If there is a high proportion of high boiling material, increased solvent residue can be left in the meal. Additional heat or steam is needed to remove the last traces of solvent. To define the extractive efficiency of a solvent, the Quality Efficiency Rating should be determined. The selective effect of isomers on extraction should also be studied. The QER factor is determined from the oil yield, refining loss and oil colour factors obtained as some solvents extract waxes and syrup in addition to oil. QER vs. BP should be studied when the suitability and economic use of solvent are required. The presence of Benzene and the toxic effect in oil as well as in cakes are undesirable. If there is no substantial difference in price, the narrow cut is preferred over the wide cut solvent. The normal losses with narrow cut solvent (10°F) are reported as 0.2% to 0.3% by weight. For a very wide cut (30-40 F) this can increase to 1.5% to 2.0% by weight. The Quality Efficiency Rating and the Boiling Points of the solvent, n-hexane, SBP 62/82°C and hydrogenated hexane should be compared. The selection of the solvent is to be made on the basis of economic comparison and its acceptibility as a food grade solvent, which is free from toxocity when left over in oil or in the meal.

TABLE (9)

DATA ON SOLVENT LOSS, CRUDE OIL YIELD AND ACID VALUE OF CRUDE OIL

Mill	Solvent Loss% 67/68	Solvent Loss% 68/69	Crude Oil Yield % 67/68	Crude Oil Yield % 68/69	Acid Value of Crude Oil 67/68 Min.	67/68 Max.	67/68 Avg.	68/69 Min.	68/69 Max.	68/69 Avg.
01.	3.5	2.9	14.9	14.6	11.4	55.8	35	15.0	50.2	38
02.	2.2	3.4	12.4	10.4	13.4	59.0	35	17.6	55.6	38
03.	4.7	3.8	12.9	15.3	7.9	30.0	25	10.4	50.4	42
04.	2.6	2.9	12.6	13.2	13.7	59.0	43	8.9	45.0	35
05.	5.0	4.9	14.2	14.9	12.7	58.4	43	8.6	40.8	30
06.	6.0	2.6	14.0	15.6	12.6	44.4	36	7.4	42.3	32
07.	4.2	2.2	14.3	13.7	12.3	50.7	41	12.3	42.0	36
08.	3.0	3.6	13.9	14.1	11.9	43.4	33	11.9	43.4	33
09.	3.9	4.6	13.3	14.3	12.0	39.1	31	10.5	42.4	32
10.	4.1	4.74	19.3	16.2	10.3	53.0	40	20.8	45.9	40

Crude oil yield in 67/68 registered 12.4% minimum and 19.7% maximum as against 10.4% minimum and 16.2% maximum in 68/69. On the average, crude oil yield can be safely taken as 13.5 to 14%. This is entirely controlled by the type of bran fed to the plant. However, the rice-bran oil extraction plant has no control over the type of bran produced. Acid value of oil, on the average, is 25 for low and AV 43 for high in 67/68, as against AV 30 for low and AV 42 for high in 68/69. The average acidity of crude oil ranges from AV 30 to AV 40; the yield of edible oil usually does not exceed 40% to 50% of the low acid oil charged to the refinery.

7.05. Crude wax obtained from pre-filtration of crude rice-bran oil contains highly cooked starch jelly as suspended impurities. As it is dissolved in oil or, in other words, oil cannot be separated from wax completely, the material is used for soap making. Crude wax yield from crude oil increases with the amount of fines present in miscella. The rice-bran oil extraction industry is constantly facing problems with fines. Many attempts were made for complete removal of fines in the miscella. The problems associated with fines are still interfering with the smooth operation of the plants. Fine wax from deodorised oil is free from fines. Here again, complete removal of fine wax from deodorized oil is not possible with the existing equipment. At present filtration in a series of bags at room temperature and separation after chilling oil to 15°C in a large plate and frame filter press are standard methods used for removal of fine wax from the edible oil. When edible oil is stored for months, solids deposited at the bottom of the container are mainly fine wax.

TABLE (10)

REFINING OF LOW ACID CRUDE RICE-BRAN OIL
AND YIELDS OF BY-PRODUCTS

Mill	Crude Oil charged		Yield of By-Products: Crude Wax		Fine Wax		Edible Oil	
	Tons	%	Tons	%	Tons	%	Tons	%
01.	1188.0		127.6	10.7	20.2	1.7	592.7	49.9
02.	931.7		139.6	14.9	3.9	0.4	454.6	48.8
03.	752.5		57.9	7.7	13.9	1.9	188.6	25.1
04.	491.5		34.9	7.1	9.4	1.9	210.2	42.8
05.	694.1		54.6	7.9	7.2	1.0	382.9	55.2
06.	362.9		92.9	25.6	0.9	0.2	161.5	44.5
07.	622.7		60.4	9.7	10.4	1.7	273.6	43.3
08.	662.9		14.8	2.2	6.2	0.9	309.1	46.6
09.	240.8		7.6	3.7	1.1	0.4	111.8	46.4
10.	239.9		97.2	4.5	1.1	0.4	93.7	39.1

7.06. Soap stock obtained as a by-product from a refinery contains roughly 30 per cent to 40 per cent of fat and is used in the soap industry. The fatty acid plant has facilities for acidulation of soap stock to produce acid oil. From the data, the annual production of fine wax is about 70 tons. A use for this valuable by-product has yet to be found. Based on its properties and the preliminary work in formulation of rice-bran wax, it can replace the carnauba wax, to some extent, as such, or after treatment with acetone or in hydrogenated form. Rice-bran wax as a principle raw material for the carbon paper industry should be explored.

The rice-bran oil extraction industry is at its development stage, though the first plant was erected in 1957. With a few years working experience in extraction of oil from rice-bran, it is not possible to answer all the problems relating to processing and control. The utmost efforts are being made to work in the area of organizing and training of technical staff, from mill operators to production managers, and reclassification of duty and responsibility for engineers. Individual plant size limits the staffing of key personnel to operate and control the plant efficiently. It is preferable to provide each plant with a production manager, trained in process work, process and cost control, organization and management, labour relation and supervision to manage the plant with authority and directly responsible to the management. The production manager should also be able to arrange for control and sequence of production, organization of labour and organization of records. A thorough knowledge of the plant should enable the production manager to carry out normal day to day maintenance, deal with emergency stops and breakdown. For major items of work, the engineer should be called in.

7.07. Though the bran oil extraction industry has developed along the line, it will take some time to achieve optimum technical standards. At present, the results of each plant are evaluated by comparing the projected operation and the actual performance of the plant. Extraction of highly rancid old bran caused a rapid corrosion in pipes and vessels, handling high acid oil and miscella. The heating coil in distillation vessels and the extractors require repairs quite often due to corrosion. Severe corrosion at the final vent pipe of the condensing system was recorded in batch plants probably due to cumulative effect of organic sulphur present in solvent. Solvent recovery systems required improvement in design for effective control of vapour, venting through the system. The present equipment installed in plants using chilled water as a cooling medium sprayed on the extended surface has a limited range, as the quantity of chilled water circulated through the packed column is fixed whereas solvent vapour in the uncondensable gas is of varying concentration. Some plants used the absorption type of recovery system using crude rice-bran oil or thin engine oil as an absorption medium. Different types of plants used different designs and therefore it is desirable to simplify the problems and develop a standard recovery system, which can work efficiently in extreme conditions.

7.08. Research and development work in the field of rice-bran oil extraction, refining, utilization and stabilization of bran are generally considered important for improved working of the rice-bran oil extraction industry. In particular, some work should be carried out on technical and economic feasibility studies of the integrated milling system (SEM) over the existing process. The study should include determination of the smallest economic unit relevant to investment costs and expected benefits. The average milling capacity of a big rice mill in Burma is about 6 to 10 lakhs baskets of paddy equivalent to 28 to 46 million pounds per year. The commercial unit of the SEM system requires at least 240 to 320 million pounds equivalent to 50 to 70 lakhs baskets of paddy per year. The average value of paddy produced in the major rice producing area is 80 to 90 lakhs baskets equivalent to 378 to 414 million pounds per year, handled by the major Zonal Organization, representing the state. In addition to the regional production of paddy, factors relating to storage facilities, geographical limit and connected routes, water resources, mode of handling and transportation should be developed before implementation of the integrated milling system. It is therefore recommended that a study on the size of the smallest economic unit of the Integrated Milling System based on the maximum available supply of paddy in the major rice producing areas in Burma should be initiated. The study should include on a broad basis, the merits of the Integrated Milling System, the cost of entire investment programme and benefits, compared to the present milling practices with conventional rice mills. Utilization of rice wax and sludges which are rich in unsaponifiable matter should be studied and at the same time, a process research should be carried out on the uses of polyunsaturated fatty acid and the hydrogenated product of varying iodine value. In the refining field, the conventional alkaline refining process should be replaced with a modern process like the miscella refining or physical refining process. The use of heat transfer medium such as Dowtherm liquid in the heating system of the deodorizer unit should be evaluated for its suitability and the method of detection for leakages.

7.09. Selection of solvent for extraction of oil from rice-bran requires special consideration on the properties of the solvent, such as sulphur and aromatic content, boiling range, vapour pressure, and physical properties suitable for the condition of the country. Process development such as optimumization of the process and the control techniques required for different plants using different types of bran, optimum solvent to meal ratio, process condition required for distillation of solvent from miscella and the meal, need constant watch to ensure that the plants are making use of the results quite efficiently. Separation of starch and small brokens in bran obtained as a by-product of high quality milling was one of the problems encountered in the extraction of oil from bran. The starch and small brokens in bran causes poor heat transfer and caking of defatted bran on desolventization. Rice-bran oil extraction industry, like any other industry, should have a research and development programme continuously engaged in the area of improvement and progress for solvent extraction, crude oil processing and utilization of by-products. More specifically, research and development in the following areas should be undertaken: (a) the development of an improved design of condensers and the solvent recovery system in conjunction with the type of solvent used and the extractive condition of the plants; (b) the development of a design of scrubbers to prevent the degradation of tocopherol in the unsaponifiable matter during the collection of sludges from different types of deodorizing equipment; (c) process research and development on utilization of rice-bran oil fatty acids for alkyd resins, preparation of an epoxy fatty acid plasticizer as an alternative to soyabean oil fatty acids, in the preparation of dimers from oleic and linoleic acid of the rice-bran oil as an alternative to tallow oleins for use in rubber plasticizers, foam polystyrene, polyvinylchloride, and paint oil, and that of hydrogenated product of polyunsaturated acids from rice-bran oil for grease making and the rubber manufacturing industry.

7.10. In conclusion, it is to be reiterated that the importance of manpower utilization in the rice-bran oil extraction industry should be recognized. Chemical engineers trained in process work should be assigned to take up actual production jobs and not the inspection or any other duty and the skilled manpower should be directed more towards field jobs and actual work in the factory and be made responsible for production supervision and control, plant safety and safe handling and storage of the solvent. More training facilities should be made available for technicians, who are actually working in the plants, in the area of processing, quality control, efficient use of fuel, power, steam, etc. Finally, more efforts, more thrust and more efficiency should be applied to many facets of operations in the rice-bran oil industry specifically in the area of industrial and chemical process technology, production scheduling and control, effective uses of utilities, handling and storage of inflammable solvents and chemicals, particularly directed to industrial plant safety and prevention of fire hazard, should be made available to production managers, plant supervisors, foremen, and process chemists, and also plant operators as immediate measures. For a long-term programme, the industrial and chemical process technology should be taught at the vocational and the technical high school level. These programmes, if effectively incorporated, will narrow the technological gap, in many areas of operations, and facilitate the operation of rice-bran oil extraction plants at the optimum level of technology.

VIII. RECOMMENDATIONS

7.11. The recommendations made here will serve as a basis for formulating a technical assistance programme needed by the rice-bran oil extraction industry:

(i) fine wax from rice-bran oil should be treated with acetone to remove oil and subsequently recrystalized with ethyl alcohol. An exploratory study on the cost of treatment of fine wax, to be used as a substitute for Carnauba wax and others in wax preparations in the pharmaceutical industry should be carried out;

(ii) methods for estimating and isolation of tocopherol and oryzanol from unsaponifiable matter of the deodorizer distillate or sludges, and wax from the rice-bran oil industry should be developed;

(iii) the quality efficiency rating and the boiling points of the solvents, n-hexane, SBP 62/82°C, and hydrogenated hexane, should be compared. The selection of solvents is to be made on the basis of economic comparison and its acceptibility as a food grade solvent which is free from toxicity when left over in oil or in the meal;

(iv) the possible use of rice-bran wax as such, or after treatment with acetone, or in hydrogenated form as a raw material for the carbon paper industry, should be explored;

(v) a study on the size of the smallest economic unit of the Integrated Milling System (SEM) based on the maximum available supply of paddy in the major rice producing area in the country should be initiated. The study should include, on a broad basis, the merits of the Integrated Milling System, cost of investment and benefits compared to the present milling practices with conventional rice mills;

(vi) research and development in the following areas are to be undertaken:

(a) development of an improved design of condensers and the solvent recovery system in conjunction with the type of solvent used and the extractive condition of the plants;

(b) development of a design of scrubbers to prevent the degradation of tocopherol in the unsaponifiable matter during the collection of sludges from different types of deodorizing equipment.

(c) process research and development on utilization of rice-bran fatty acid for alkyd resins; preparation of an epoxy fatty acid plasticizer as an alternative to soybean oil fatty acids; in the preparation of dimers from oleic and linoleic acid of the rice-bran oil as an alternative to tallow oleins for use in rubber plasticizer, foam polystyrene, polyvinylchloride and paint oil; and that of the hydrogenated product of polyunsaturated acids from rice-bran oil for grease making and in the rubber manufacturing industry;

(vii) to establish training facilities, specifically in the areas of industrial and chemical process technology, production scheduling and control, effective and economic use of utilities such as fuel, power, water, steam, and handling and storage of inflammable chemicals and solvents, particularly directed to the industrial plant safety and prevention of fire hazard, should be made available to production managers, plant supervisors, foremen, process chemists and also plant operators as immediate measures. For a long-term programme, the industrial and chemical process technology should be taught at the vocational and the technical high-school level. These programmes, if effectively incorporated, will narrow the technological gap, in many phases of operations, and facilitate the operation of the rice-bran oil extraction plants at the optimum level of technology.

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