OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

15300

Distr.
LIMITED

IO.10
23 November 1987

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

ENGLISH

THE RICE BRAN OIL REFINING TECHNOLOGY*

Prepared by

U MYINT PE
UNIDO consultant

* This document has been reproduced without formal editing.

V.87 91951

ABBREVIATIONS

AV	- Acid Value
°C	- Degree Centigrade
FFA	- Free Fatty Acid
HAV	- High Acid Value
LAV	- Low Acid Value
mfb	- Moisture free basis
ml	- milli-litre
psig	- pound per square inch gauge
RH	- Relative Humidity
Sfb	- Solvent free basis
Vol	- Volume
Plant (A)	- (01) Kamayut Continuous Rice Bran Oil Refining Plant, Rangoon, Burma.
Plant (B)	- (17) Bassein Continuous Rice Bran Oil Refining Plant, Burma.
Plant (C)	- Central Vegetable Oil Refining Co. (CENVOCO), Manila, Philippines.

TABLE OF CONTENTS

		Page
1.	INTRODUCTION	1
2.	RAW MATERIAL RESOURCES	4
2.1	Freshly milled rice bran	4
2.2	Stablised rice bran	6
2.3	Parboiled rice bran	6
2.4	Rice bran stored under low temperature condition	7
2.5	Rice bran stored under atmospheric condition	8
3.	RICE BRAN OIL PROCESSING	9
3.1	Prefilteration process	12
3.2	Degumming process	13
3.3	Dewaxing process	13
3.4	Alkali refining process	17
3.5	Deacidification by steam - refining	22
3.6	Deacidification by Fractionation	23
3.7	Decolorisation by adsorption	26
3.8	Deodorisation by steam - vacuum distillation	28
4.	CONCLUSION AND RECOMMENDATION	30
5.	APPENDIX	
6.	BIBLIOGRAPHY	52

LIST OF TABLES

Table		Page
1	Change in Acidity of Milled Rice under Low Temperature Condition.	33
2	Study on Growth of FFA (%) in Freshly Milled Rice Bran during storage under Room Temperature.	34
3	Study on Growth of FFA (%) in FRB stored under Room Temperature.	35
4	Growth of Acidity in Heat Stablized Bran.	36
5	Growth of Acidity of Parboiled Bran obtained from pilot-scale processing of Parboiled Paddy under 48 hour steeping, 12 minutes steaming at steam pressure 60 psig.	37
6	Growth of Acidity of Parboiled Bran obtained from Henzada during storage.	38
7	Growth of Acidity of Parboiled Bran obtained from Kyauktaga during storage.	39
8	Increase in Acidity during storage in Winter.	40
9	Decrease in Total Extractable Oil Content of Brown Rice during storage.	41
10	Decrease in Surface Fat Content of Ngakywe type Milled Rice during storage.	42
11	Degumming by Hydration with different amount of water.	43
12	Degumming of Prefiltered Crude Rice Bran Oil using different concentration of Concentrated Phosphoric Acid.	44
13	Winterization of Fully Degummed Crude Rice Bran Oil at 12°C.	45

Table		Page
14	Recovery and Yield in different stages of Refining Crude Rice Bran Oil.	46
15	Separation of LAV Fraction from Fully Pretreated HAV Crude Rice Bran Oil by Fractional Crystallization in Solvent Media.	47
16	Deacidification of Fully Pretreated LAV Crude Peanut Oil under Varying Acidity Range by Multiple Fractional Crystallization.	48
17	Deacidification of Fully Pretreated LAV Crude Sesame Oil under Varying Acidity Range by Multiple Fractional Crystallization.	49
18	Deacidification of Fully Pretreated LAV Crude Rice Bran Oil under Varying Acidity Range by Multiple Fractional Crystallization.	50
19	Deacidification of Fully Pretreated Crude Rice Bran Oil under Varying Acidity Range by Multiple Fractional Crystallization.	51

1. INTRODUCTION

Food and food by-products are of the greatest importance to the economic needs of any countries. This is more, especially the case where important diatry items have to be imported where they can be manufactured at a lower cost domestically.

Rice being the major crop of most of the countries in South East Asia, is the principal commodity for export and local consumption. An inescapable by-product of rice milling is rice bran which is also widely known as an oil bearing material. Rice Bran amount to approximately 10 to 11% of the paddy by weight depending upon the variety of paddy, the grade of the milled rice and the degree of milling. The bran being rich in fatty matters, protein and vitamins has a high nutritive value. For this reason,it has been valued as animal feed and in some countries, it is used as an industrial raw material for extraction of oil.

Immediately after milling, the bran will contain 3% or less of free fatty acids. Unless oil in the bran is extracted immediately or the bran stablised, free fatty acids are known to increase rapidly. The maximum rate of increase is about 1% per hour at 77°F. The average being approximately AV 70 to 80 after two to three months storage.Complete hydrolysis does not occur. However, the fatty acids are also subject to attack by the oxygen with the formation of fats peroxides and other oxidised products, typical of rancid fats and oils.

Oil can be extracted from bran which may have low or high acidity depending on the condition and length of storage. The rapid growth of free fatty acid in the bran after milling has been recognised as a serious problem for the rice

bran oil industries in the rice producing areas.The principal causes of deterioration of oil in the bran during storage were due to activity of enzyme lipase in the presence of moisture. Temperature and the relative humidity of the storage atmosphere favour the deterioration of oil in the bran. The average temperature of the rice growing countries registered all year round is one of the factors effecting the deterioration of the oil in the bran during storage.

On the other hand, storage ability of bran in much colder climate such as Japan is much better than other countries in South East Asia. For this reason and also as a result of the unique rice milling system, Japanese rice bran oil industries enjoyed the economic success. To retard rapid formation of free fatty acid in the bran during storage, many methods of stabilization were developed in the past decades. Commercial stabilization plants are in operation in some countries. Japan is currently importing stabilised rice bran from United States as a raw material for her rice bran oil industries.

Extraction of oil from freshly milled rice bran is still practised as a basic approach to overcome the acidity problem. Some prefer construction of bigger capacity rice mills to provide fresh rice bran for rice bran oil extraction plant, attached to it. Others practised smaller capacity rice bran oil extraction plant in the areas where the rice mills are in the economic radius of these small plants. Each country plans to suit the infrastructure of the existing rice milling industries.

Under these circumstances, fresh rice bran are still regarded as a much needed raw material for the production of edible rice bran oil and the use of fresh rice bran does not only lend itself to overcome the rapid growth of acidity but also produce a quality edible rice bran oil with nutritious de-oiled rice bran. Stablised rice bran could be a good supplement

for increased production of edible rice bran oil. Parboiled rice bran is preferable for its high oil content and storage ability. As a result of research and development works on cold storage of milled rice, at -15°C and +10°C (Table 1) and the success of Japanese rice bran oil industries (20), bran can be stored under suitable cold storage condition which may prevent rapid growth of acidity in the bran.

Nevertheless, rice bran oil industries in South East Asia produce more high acid crude rice bran oil than low acid value crude rice bran oil as a result of extracting 3 to 4 months old rice bran. The ratio of high acid value to low acid value crude rice bran oil is as high as 80: 20. (12) The crude rice bran oil derived from freshly milled rice bran, stabilised rice bran or parboiled rice bran still contains acidity around AV 30 - 40. A large portion of crude rice bran oil produced in the rice growing countries contain acidity as high as AV 50 - 60. Crude rice bran oil with acidity as AV 60 or more are classified as an industrial oil for soap making.

Alkali refining of crude rice bran oil in either batch or continuous plant is feasible only when the acidity of crude rice bran oil is not more than AV 40. In some places, alkali refining of crude rice bran oil with acidity as high as AV 50 - 60, are practised at the expense of high neutral oil losses and the quality of edible oil.

The quality of edible oil produced from high acid crude rice bran oil is poor and off-flavor with brownish yellow color. Some workers (25) suggested predistillation of high acid rice bran oil to lower the acidity of the oil to AV 40, followed by conventional refining. Others (12, 19) advocate on application of physical refining techniques for production of edible oil from

high acid crude rice bran oil. In addition to removal of impurities such as unsaponifiable matters from high acid rice bran oil prior to physical refining, phosphorus and iron content of the crude rice bran should be kept at an acceptable minimum value of 50ppm for phosphorus (P) and 2 ppm for iron (Fe).(18).

All these processes demand thorough removal of phosphatides, proteins and non-glycerides material prior to separation of free fatty acid. The economic of processing edible rice bran oil from different quality of crude rice bran oil depends largely on the removal of non-glycerides present in the oil. A special attention is given to identify the process which could effectively separate these non-glycerides materials from the crude rice bran oil with varying acid content.

2. RAW MATERIAL RESOURCES

2.1 Freshly milled rice bran

Rice bran collected immediately after milling and subsequently transported to the rice bran oil extraction plant within 24 to 72 hours is generally termed as fresh rice bran. It can also be defined as the bran when extracted at the oil extraction plants yield a crude rice bran oil with acidity less than AV 40. The rate of production of rice bran in average rice mill with an intake capacity of 4 tons per hour would yield one half ton per hour bran. If the frequency of collection of rice bran in every rice mill is assumed once a day with a minimum transportation and handling time of 6 to 8 hours, the fresh rice bran when delivered at the oil extraction plants will be already 30 - 40 hours old.

A study on growth of acidity of freshly milled rice bran on hourly and daily basis showed that the increase in

acidity of the bran was appreciable and in close agreement with the commercial data. (Table 2,3) Although the rice bran extraction plant may be located within the economic radius of the existing rice mills in the developing countries, collection of fresh rice bran in practice was still difficult and time consuming due to bulkiness of the rice bran, condition of the access roads to the rice mill and capacity limitation of the carriers. The free fatty acid contents and the life of fresh rice bran predicted in previous paragraph were based on collection effected by land transportation. In some areas the transport of fresh rice bran can be made only by riverine craft due to peculiar location of the rice mills.

Fresh rice bran immediately after milling was made available for oil extraction in some integrated rice milling complexes, in Philippines and Thailand. The National Food Authority of Philippines has constructed a continuous rice bran oil extraction plant, SPGC Tacurong, with a capacity of 60 tons per day rice bran, close to the rice mill capable of milling 600 tons paddy per day. Fresh rice bran produced was directly fed to the rice bran oil extraction plant via mechanical conveyors. Similarly 1 x 100 tons rice bran per day continuous extraction plant was installed in a large rice mill with milling capacity of approximately 1000 tons paddy per day, owned and operated by Messrs. Meh Boon Krong Intergrated rice storage and processing complex, Pathanthanee, Thailand. Bigger capacity rice milling complexes are common in the United States.Comet Rice Mill, Houston, Texas, Farmers Rice Cooperative, West Sacramento, California, Riviana Foods Inc., Houston Texas and Uncle Ben's Inc., Houston, Texas in the United States are a few mantioned here out of many milling complexes for rice and rice-products. (26)

2.2 Stablised Rice Bran

The rapid deterioration of oil in rice bran is the result of fats transformation reaction which starts right after milling. These are mostly enzymic reaction which begin with the damage of fatty cells in the scouring process to continue more or less quickly depending on temperature and moisture content. This flavour changing reaction may be prevented or impeded by inactivating enzymes through heat. (16) Moist heat stabilization technique is very similar to the parboiling process where paddy was first steeped ,then steamed and dried to low temperature level before the ordinary milling process. The bran layers inside the paddy grain get stabilised and enzymes deteriorated by steaming and drying.

Similarly, rice bran as it comes out from the rice polishing cone is immediately steamed and dried at 100°C to a safe moisture level of 3 - 4% to slow down the growth of acidity. Stablised rice bran produced by a suitable method such as this could be a good supplement for extration of edible rice bran oil. Stablised rice bran are produced commercially for oil extraction in some developing countries. If properly processed, the stabilised rice bran can be stored for 2 - 3 months under ordinary atmospheric conditions. (Table 4)

2.3 Parboiled Rice Bran

Various quality of parboiled rice were produced conventionally in Burma, India, Pakistan, Thailand and Banagladesh for export, and local consumption. Parboiled rice bran is the major by-product of parboiled rice milling. It is widely known in these countries for its higher oil contents and keeping quality of the bran. Parboiled rice bran derived from properly processed parboiled paddy can be stored upto 6 months without much deterioration to the bran. (Table 5) The acidity of the parboiled rice bran can be kept as low as AV 30, if the

parboiling is carried out under optimum process condition.(21) However, the existing parboiling technique commonly employed in the parboiled rice producing countries are directed only towards the improvement of quality and recovery of parboiled rice. None of these dealt with improved stability of parboiled rice bran.

A research project was carried out in the past years on the development of a process on parboiling of paddy which will improve stability of parboiled rice bran. An optimum process condition was thus established at 48 hours steeping, 12 minutes steaming at 60 psig steam pressure followed by drying to the moisture level of 11%. (21) The quality of parboiled rice bran produced in two different areas differed considerably. (Table 6,7) Under suitable parboiling condition such as optimum process established in the laboratory scale processing of parboiled paddy, quality parboiled rice with better recovery and best quality parboiled rice bran can be realized.

If further commercial application of this parboiling condition could be achieved, parboiled rice bran will be most dependable raw material for the production of edible rice bran oil.

2.4 Rice Bran Stored Under Low Temperature Conditions

Lipase activity in rice bran can be slowed down by keeping it under cold storage atmosphere. Recent study (9) on deteriorative changes of milled rice under -15°C and +10°C has revealed that the acidity growth of oil in the rice can be controlled under cold storage conditions. (Table 1) This phenomenon was independently confirmed by Yokochi (25) in his study on growth of acidity in Japanese rice bran in winter.(Table 8) These conditions as evidenced by the success of Japanese rice bran oil industries could be further developed for commercial

application. However, the size, type and the capacity of cold storage has yet to be determined for each rice mill. Cold storage facilities can be designed at lower cost as most modern rice mills operate on a source of power derived from rice husk which are abundant in the rice mills. The choice of chilling unit in conformity with the source of power available in the rice mill should be decided prior to designing any other components of the cold storage for rice bran.

2.5 Rice Bran Stored Under Atmospheric Condition

This type of rice bran is originated from irregular collection of rice bran which is considered as a last priority item for transportation in the paddy season. A decrease in oil content of stored products such as brown rice and milled rice was observed in the study carried out recently.(9) The rice bran being widely recongised as an important industrial raw material for oil extraction and animal feed should not be stored unnecessarily for longer period under ordinary atmospheric condition.

Long storage of rice bran not only deteriorate the oil in the bran but also reduce the total extractable oil content. (Table 9,10) Rice bran stored for 1 to 2 months under normal atmospheric condition will show unusually high in free fatty acids. (Approx. AV 70-80) The crude rice bran oil with acidity beyond AV 60 is regarded as a raw material for soap making. The acidity of these oil are extremely high that ordinary alkali refining process could not be employed for the production of edible oil. Dark brown colour of these oils is difficult to bleach also. Crude rice bran oil with acidity upto AV 70 - 80 were produced in a large proportion as the rice bran oil industries required continuous flow of raw material rice bran for uninterrupted operation of the plants.

3. RICE BRAN OIL PROCESSING

Rice bran oil like any other vegetable oil such as groundnut, soybean, etc., contains a large proportion of triglycertices of fatty acids and a small quantity of some minor components. Free fatty acid content in the crude rice bran oil varies with the quality of rice bran used as raw material for oil extraction. The best quality rice bran is the one that has been collected immediately after rice milling. The oil in the bran get deteriorated when the bran is stored for more than a few days or so in the atmosphere of hot and humid climate.The presence of enzymes in the rice bran as influenced by the temperature and the relative humidity of the ambient atmosphere favour the condition for the rapid increase in the acidity of oil in the bran.

Due to unusually higher percentage of free fatty acids present in the crude rice bran oil, the processing of edible oil from it by alkali refining was found difficult.It sounds rather uneconomical for production of edible oil if the crude rice bran oil contains acidity higher than AV 40. The crude rice bran oil with acidity less than or upto AV 40 is arbitarily chosen as a low acid oil. It has yellowish green color.The color of crude rice bran oil turns exceedingly brown as free fatty acid increases. High acid crude rice bran oil appears to be dark brown in color.

Presence of minor components such as coloring matters, waxes, sludges and phosphatides in the crude rice bran oil cause undesirable losses of neutral oil during different stages of processing. In the usual refining processes, the crude rice bran oil is first subjected to prefilteration in a plate and frame type filter press at room temperature to remove solid substances and high melting waxes, proteinacious materials,carbohydrates, etc. The filtered oil is subsequently treated with

a small amount of phosphoric acid (0.1 to 0.6%) by weight to separate gummy substances.

Water is sometimes added to promote removal of hydratable phosphatides. An aqueous sodium hydroxide solution, is added to neutralize free fatty acids. The solution was prepared from calculated amount of sodium hydroxide, in a suitable volume of water to form a desired concentration. The soapstock thus formed is separated by settling or centrifugation. The neutral oil is washed several times with warm water to eliminate traces of soap particles. Moisture in the oil is further removed in a vacuum drying unit, where the oil is sprayed against hot air under vacuum. The oil coming out of the vacuum dryer is treated with a small percentage of activated carbon or clay for decolorization. Then, the spent earths are later removed by simple filteration in the filter press.

The bleached oil is then deodorized in a steam-vacuum-distillator under fairly high temperature for the separation of odorous matters and some oxidised products. The deodorized oil is subjected to winterization to remove high melting waxes. The stable waxes after long hours of crystallization under low temperature are filtered off in a plate and frame filter press.

In normal practice, alkali refining of vegetable oil is limited to the acidity level of AV 10-20 (5 to 10% ffa). The free fatty acid content of vegetable oil such as soybean, cotton seed, corn, sunflower, groundnut, palm oil etc. seldom reached beyond this acidity range. Rice bran oil is exceptionally high in acidity. The crude rice bran oil with free fatty acid content less than AV 40 are commercially processed by alkali refining to produce edible oil.

In some countries, the proportion of high acid to low acid crude oil is high. The crude rice bran oil with acidity less than AV 40 are available only in the paddy season, which begins with the harvesting of paddy and ends in 3 to 4 months after. Under these circumstances, the crude rice bran oil with acidity as high as AV 50 - 60 should be processed in commercial scale by alkali refining for edible purpose at high neutral oil losses, off taste and inferior in quality.Moreover, high acid crude rice bran oils are difficult to refine. The processing of high acid crude rice bran oil by alkali refining is found unsatisfactory in terms of economic and the quality of edible oil.

To overcome these age-old problem and technical difficulties encountered during refining of high acids crude rice bran oil, some (19) advocate application of physical refining or steam distillation to achieve recovery of edible oil and valuable mixed fatty acids as by-products.

As an alternative, deacidification of high acid rice bran oil by steam distillation and mild alkali refining is practised in some countries. (25) The acidity problem in rice bran oil industry is still stagnant, despite many development works are carried out in the past few decades. To ensure increase in production of low acid rice bran oil for edible oil processing, use of freshely milled rice bran is still considered economically and technically most desirable. Other known pretreatment processes for rice bran such as stabilization, extrusion etc. have to be incorporated to control rapid growth of free fatty acid in the bran. Profitable merger of oil extraction plant and modern rice milling complexes should also be encouraged. (25) Parboiled rice bran should also be utilised effectively as source of low acid rice bran oil, despite many technical problems encountered in the extraction of oil in batch or in rotary batch equipments due to its high oil content. (15)

These and many more efforts are considered primarily as an important measure to control the acidity of crude rice bran oil. In addition to conventional alkali refining and steam distillation method, currently employed in the processing of edible oil from low acidity crude oil, high acid oil refining technique is being developed recently, (23) to encounter acidity problem in the rice bran oil industry. This technique, however, demands a thorough treatment of crude rice bran oil to separate non-glycerides and other gummy substances, prior to removal of free fatty acids. With this innovation, the crude rice bran oil with acidity upto AV 70 - 80 could be used as a source of raw material for edible oil production.

In order to achieve tangible results, it is extremely important to search for suitable methods of eliminating nonglycerides materials including different types of phosphatides, waxes and other impurities. A detail outline of these interrelated processes are given in the following paragraphs.

3.1 Prefilteration Process

Rice bran oil contains sludges, proteinacious substances, high melting waxes, gums and mucilages, varies according to extraction solvent, type of equipment and the raw materials. These substances can be visibly seen when the oil is kept for a number of days in the storage tanks. However, these materials are difficult to separate industrially. Bag filters are introduced in the separation of these substances. The rate is low and the solid sludges contain a higher percentage of liquid oil. The oil losses are also significant.

Prefilteration of crude rice bran oil in plate and frame filter press at room temperature is found fairly efficient. In addition to filter cloth, filter papers are used to improve the separation. A plate and frame filter press with low

pressure pump and large surface area is desirable for better result. The continuous centrifugation is not suitable for this purpose as the sludges and mucilages are sticky and gummy. Sludges vary according to the quality of crude rice bran oil.

3.2 Degumming of Prefiltered Crude Rice Bran Oil

Gums and mucilages in vegetable oil are complex mixture. The most common impurities in the oil comprise phosphatides and glycolipids with some sugar and protein complexes in colloidal form. (6) The normal method of degumming involves the use of small quantities of concentrated phosphoric acid under moderate temperature followed by filteration or settling. Direct steam injection may be carried out until the temperature reaches 80 - 100°C by which sufficient steam will have condensed to hydrate and floculation of the gums. These are removed by centrifugation. (6)

In the usual process, the crude oil is first treated with 2.5% (vol) of water to hydrate the hydratable phosphatides in the oil at 80 - 100°C. The gums are removed by centrifuge. (Table 11) To the dislimed oil which usually contains about 0.5% to 1.0% of nonhydratable phosphatides, a small quantity of concentrated phosphoric acid (0.1 - 0.6% by wt) is added at the oil temperature of 80 - 100°C. (Table 12) The non-hydratable phosphatides are converted to hydratable one by the action of concentrated phosphoric acid where the Ca and Mg ions are released. (15)

3.3 Dewaxing by Winterization

In the extraction of oil from rice bran, a certain amount of wax is removed with the oil. Waxes are one of the classes of substances of plants or animal origin that differ

from fats in being less greasy, harder and is containing principally ester of higher fatty acids and alcohol and saturated hydrocarbon. The wax content of crude rice bran oil varies from 9% to 18% dependent on many factors such as variety of rice, techniques of milling process, method of oil extraction,quality of solvent and extraction temperature.

Overview of the literature references on winterization as given in the following paragraphs are of some value for further development of a suitable dewaxing process.

Bailey (2) stated that winterization of vegetable oil in general is defined as the process by which the higher melting glycerides are removed from oil. The separation was formerly carried out by simply allowing the oil to stand and settle out in outside tanks during the winter.A large demand for such oil makes it necessary to employ artificial cooling and filteration of the liquid from the solid portion.

Kerchembauer (8) described the winterization as the process for the partial removal of saturated glycerides. These glycerides have relatively high melting point and possess only a limited solubility in the unsaturated glycerides.Many oils which are clear and completely liquid in summer are converted at winter temperature into milky looking product of undesirable appearance because of precipitation of saturated fats.

Harris (6) also reaffirmed that winterization is a process for the removal of high melting saturated glycerides. Rice bran oil is eminently suitable for this application since the glycerides structure follow a more even distribution than most soft oil. Winterization consists of chilling the rice bran oil very slowly in a large tank and holding it at 5°C lower for a number of days. The saturated glycerides that crystallize out are separated by filteration.

Commercial dewaxing by winterization carried out in the rice bran oil plant (A) (B) and (C) are given as in the following paragraphs. In the rice bran oil plant (A) the removal of waxes are effected by:

(1) Precooling of deodorized oil in the deodorizer from 180°C to 40°C by circulation of cooling water through the coil while the contents are kept under vacuum.

(2) Winterization by chilling to 15°C in two vessels of closed design provided with mechanical stirrer, cooling coil and insulation, each having a capacity of 4 tons/batch.

(3) Separation of waxes is carried out in 1500 mm X 1500 mm x24 plates filter press, provided with a displacement pump of low pressure design. Filter papers are inserted between the plates in addition to filter cloth for better filteration of waxes.

In the rice bran oil plant (B) winterization is carried out before deodorization stage. Two vessels provided with mechanical stirrer, cooling coil and insulation of closed design, each having a capacity of 3.5 tons are used for primary chilling of the bleached rice bran oil. Cooling is effected by circulating chilled water to 15°C by means of a refrigerator.The plate and frame filter presses constructed of steel and cast iron are used in the separation of waxes at 15°C. The winterization of bleached rice bran oil in this plant is of batch design.

Winterization of deocorized rice bran oil in the rice bran oil plant (C) was carried out in a semi-continuous system. The deodorized rice bran oil at 50°C was chilled to 15°C by spraying the oil to the surface of the chilling roll, rotating at 12 rpm. Multiple pass continuous system is designed to chill 3 tons rice bran oil in 2½ hours. The chilled oil is then pumped into an insulated tank fitted with cooling coil, agitator and pump for recirculation. The chilling roll is 5 ft in diameter and 6 ft long

of mild steel construction. Electrically driven geared motor is used to rotate the roll at 12 rpm. Chilling is effected by direct expansion of NH_3 through the shaft to the inside surface of the roll. The crystallized waxes are separated in two plate and frame filter presses of 18" x 18" x 24 plates each. Filter papers are inserted for better results, in addition to filter cloth. (27)

Recent research work carried out in dewaxing of rice bran oil by dry fractionation was found to be encouraging. (7) Obviously, it differed from winterization in many ways. Winterization does not require pre-melting of the oil around melting point of the sample. The temperature, stirring rate and fractionation time is more specific in dry fractionation than winterization.

Although winterization is primarily a process for separation of high melting saturated glycerides from liquid fats and oils, it can be equally employed in the removal of rice bran waxes, if modification is made for improvement. In order to achieve effective dewaxing of rice bran oil, winterization should be modified in the following areas.

(1) Preheating of rice bran oil to about 70°C;

(2) The sizes of the crystals formed during chilling process are controlled by means of a time-temperature curve; and

(3) Desired degree of dewaxing is measured in terms of unsaponifiable matter content.

The modified winterization - dewaxing method is similar to dry fractionation or fractional crystallization process where the size of the wax crystals is controlled by time-temperature correlation during chilling process.

As a result of study carried out in the past years (7) an optimum dewaxing condition was established in the laboratory at the final chilling temperature of 12°C and the crystallizattion time of 3 hours with adequate agitation. (Table 13) On the basis of this established condition, a commercial scale dewaxing plant may be designed for removal of waxes from rice oil.

3.4 Alkali refining process

Alkali neutralisation is a process commonly used to separate free fatty acids present in the oil forming soap which are removed by settling or centrifugation. More alkali is usually added than is necessary for neutralisation of the free fatty acids. An amount of caustic solution based on the free fatty acids content of the oil plus some excess is added into the crude oil and mixed. Schwitzer (17) stated that good quality fats required 10 to 25% excess of caustic soda for neutralisation.The strength of the solution is as a rule between 20° and 23° Be.

After separation, light phase discharge consist of the refined oil containing traces of moisture and soap,insoluble materials, free caustic, phosphatides and a small quantity of neutral oil. A neutralised fat has a lighter colour than the crude fat due to pigment being removed along with the soap.(10) Refined oil is washed with 10 to 20% by weight of soft water at 90°C. The water washing process removes about 90% of the soap content in refined oil. The remainder of the soap is removed in the bleaching process. During water washing, a certain amount of hydrolysis of fat occurs which however is not significant from the point of view of fat loss. After the fat had been washed,the small amount of water (0.5%) remaining in the fat has to be removed. This is done by heating the fat under vacuum causing the water to evaporate.

Takishita (20) observed the contacting period of oil and alkali in old batch process as 10 to 60 minutes and breaking period and settling time from 1 to 10 hours. Under this experimental condition, the refining loss is 1 - 1.1 x ffa % x 2. The quality of oil and the yield were improved in recent years. The continuous refining processes of different design were developed between 1950 to 1960. Sharples low loss process, All-hemetic short-mix continuous refining process by De Laval of Sweden and Westfalia continuous refining process are currently known for refining of rice bran oil. These continuous processes save the refining loss about 10 to 20% of the standard caustic process of batch design.(20)

Harris (6) reaffirmed that the refining losses are associated with the concentration of caustic soda used in the neutralisation process. A firmer soapstock are obtained from saponification of fats rich in saturated glycerides (hard fat) whereas soft soap are usually produced by unsaturated glycerides fats. Some constituents of high melting wax fraction in the oil also contribute high refining losses. Moreover, difficult separation of soapstock from residual neutral oil also causes high refining losses. Various quality of soapstock can retain a considerable amount of neutral oil.

In the refining of fats and oils in general, Bailey (2) described that alkali refining removed free fatty acids in the oil almost completely and converted to insoluble soap.Other acidic substances like waxes, combine with alkali and there is probably some removal of impurities from the oils by adsorption on the soap formed in the operation. Almost all substances are removed which become insoluble upon hydration. Caustic soda is commonly employed for the removal of free fatty acids. It has disadvantages however of saponifying a small proportion of neutral oil.

The technology of alkali refining involves primarily with the proper choice of alkali concentration and refining techniques which directly effect the desired degree of purification without excessive saponification of neutral oil with appropriate method for separation of refined oil and soapstock. The amount of caustic soda required for nautralisation could be calculated stoichiometrically on the basis of the free fatty acid content. The strength of lye solution is expressed in terms of specific gravity as degree Baume.

In continuous processing of crude oil, Carr (3)pointed out the improvement in refining efficiency influenced by the factors as (1) upgrading the average quality of crude oil; (2) evaluating the effect of variables in each refining stage and (3) providing improved equipment for flow control, pumping, heat exchange, mixing, separation and instrumentation. The success of the refining process depends largely on uniform feedstock, proper quality of refining agent, proper mixing of reagent and oil, proper contact time and temperature control and efficient centrifugation. Feedstock should be evaluated for free fatty acids,neutral oil or cup loss and bleach test on cup refined oil. In the preparation of caustic solution concentration, flow rate and temperature should be carefully chosen. Caustic strength of 17 to 18° Be are usually recommended for vegetable oil containing a large proportion of unsaturated glycerides.

Most oil are refined with 5% to 10% excess of caustic soda. Sufficient blending of caustic solution and the oil is in such proportion as to ensure adequate contact with the free fatty acids, phosphatides and colour pigments. Caustic reacts with free fatty acids to form sodium salts of fatty acids (soap) while hydrolysing phosphatides and removing unsaponifiable matters from the oil. Subsequently, soap and neutral oil mixture are fed to the mechanical separator at a temperature suitable for optimum operation. Most soft oil and the soap mixture are heated to 74°C

to break the emulsion of the mass. Saponification rate of neutral oil increases with the oil temperature during mixing of caustic. In the water washing of refined oil, the oil is reheated to 88°C while preheated soft water is pumped into the refined oil at a rate of 10 to 20% by weight of oil flow. Residual soap in the refined oil are transferred from oil to water phase. The soapy water-oil mixture continues through secondary separator.

The temperature of washed water is 5 to 8°C higher than the oil to prevent emulsion. Washed oil at 82°C is dried in a continuous vacuum dryer. The oil is cooled to about 49°C before entering the refined oil tank. Yokochi (25) proposed a refining process of rice bran oil in a semi-continuous system commonly used by the rice bran oil industries in Japan. Crude rice bran oil with acidity AV 30 is subjected to degumming and predewaxing operation. About 0.1 to 0.3% phosphoric acid is added for degumming. The gums and crude wax are separated by Misco type supper centrifuge. Under Japanese condition, yield of 4 to 6% gums and waxes are reported. The degummed and dewaxed oil is subjected to first neutralisation with weak alkali solution of 16 - 18° Be concentration at the oil temperature of 30 to 35°C. The amount of caustic soda added is such that about 3% free fatty acids are removed in this stage. Oil and caustic soda solution are thoroughly mixed and then separated by Misco type super centrifuge at the temperature of 40 to 45°C.

After addition of 0.1 to 0.3% phosphoric acid by weight to the oil at 35 to 45°C, the mixture is stirred for 1 hour. About 1.2 to 1.4 times the calculated amount of caustic soda is added and then stirred. The foots (soapstock) are then separated by Misco type centrifuge. Washed water at 60 to 65°C at the rate of 1:1 ratio to oil is added and the solution is stirred. The first washing is decanted by settling. Similarly, second water washing is effected at the temperature of 75°C.

Washed water are separated by settli: g. Final water washing is carried out at the temperature of 85°C to dissolve or coagulate alkali, soap and other water soluble substances in the oil.Washed water is separated by settling while the emulsified layers are separated by centrifugation.

About 0.02 to 0.05% of phosphoric acid is added to dehydrate oil at the temperature of 35 to 40°C and the content are stirred for 30 minutes. About 2% by weight of activated clay is added and the mixtures are stirred under vacuum while the temperature of the oil is raised to 80°C. Further addition of 2 to 3% activated clay is effected under vacuum and the mixtures are heated to 120 to 125°C and stirred vigorously. The spent bleaching earths are removed by filteration. The bleached oil is deaerated and charged to the deodorizing vessel. The temperature of the oil is rapidly raised to 200°C. At 220 to 230°C, superheated steam is injected to effect deodorization of the oil under 3 - 4 mm absolute vacuum. About 4 to 5 hours is required for deodorization to remove odorous substances. The amount of steam added to the deodorizer is about 5% by weight of oil. Cooling of deodorized oil is carried out under vacuum to the temperature of 50°C. Dewaxing is effected in cooling tank at the temperature of 0 to 3°C. The crystallised waxes are removed after 48 to 72 hours duration. Activated carbon (0.1%) with diatomatious earth 0.5 to 1% are added to the oil at 10 to 15°C and filtered.

An over all yield of 56 to 58% edible oil is achieved by this process for the crude rice bran oil having an acidity of AV 30, (15% ffa). This established data reported by Yokochi (26) was independently compared with that of actual commercial scale refining of crude rice bran oil under similar acidity range. (Table 14) The edible oil yield of 60.62% was reflected in the commercial scale alkali refining of crude rice bran oil having

an acidity of AV 25.08 (12.54% ffa) in the batch refining plant. (27)

3.5 Deacidification by Steam refining

In recent years there is a trend to replace the alkali neutralization process of free fatty acid with steam refining.(5) In 1930, physical refining was applied as a process for partial removal of free fatty acid content.(28) Direct caustic soda refining would have given looses of neutral oil. Later, it appeared possible to obtain edible product by physical refining of coconut oil, palm kernel oil and tallow, if proper treatment was applied before distillation. In 1950, physical refining was extended for use in the processing of another high free fatty acid oil viz: palm oil.

The basis of the technique is the use of deodorizer for steam distillation of fatty acid as well as odorous volatile matters from the oil. Present experience show that oil cannot be deodorized satisfactorily unless most of the phosphatides have been removed. Some vegetable oils such as soybean oil containing phospholipids possess a problem in physical refining. In the water degumming of soybean oil, non-hydratable phospholipids still remain which may be subsequently removed in the alkali refining. Some workers (5) recommended acid degumming after pretreatment with water followed by pretreatment of the oil with bleaching earth. The effect of various adsorbents were also evaluated in the removal of phospholipids and pigments in recent years.

The crude feed stock should be thoroughly pretreated for removal of gums (phospholipids), [illegible]e metals, pigments, and waxes. Without an effective pretreatm[illegible] the steam refining stage cannot be expected to produce an [illegible]il of color and stability characteristic comparable to the commercially accepted quality

of refined product. The extent of pretreatment stage is dependent on the particular oil and its quality. Some require simple pretreatment system while others require vigorous degumming stages.

A rule of thumb specification regarding the stability to steam refining for soybean oil is that crude soybean oil should not contain more than 2 ppm iron (Fe). It also stated that the crude oil should be water degummed to an oil containing not more than 50 ppm phosphorus (P) and not more than 50 ppm Ca and Mg ions.(18)

Pandurang (12) proposed a process for conversion of non-edible rice bran oil to edible grade rice bran oil diagramatically. No further description of the process was given in his paper. Although, soybean oil, corn oil, coconut oil, babasu oil, palm oil and palm kernel oil as well as tallow and lard were successfully processed by physical refining in the laboratory scale apparatus, the crude rice bran oil with acidity more than AV 40 is still not in the list of physical refining process. (19) High acid rice bran oil of acidity greater than AV 40 has yet to be explored for possible refining by steam distillation method.

3.6 Deacidification by fractionation

For the removal of free fatty acids from crude fats and oils, various processes, such as solvent extraction,distillation, reesterification and alkali neutralization are employed commercially. The choice of a suitable process may depend largely on the type and quality of fats and oils. Extraction of free fatty acids from oil with alcohol or other solvent having a greater affinity for free fatty acids than for glycerides have often been proposed. When a mixture of a crude oil and alcohol is brought to equilibrium at a temperature at which the system consists of 2 phases, the alcohol rich phase contains a much higher concentration of free fatty acid than the oil rich phase. (23)

It has been reported that when a mixture of alcohol and glycerol are used as solvent for deacidification of olive oil, the reduction in acidity from 55% free fatty acids to 14% was obtained. This condition was achieved when 100 parts oil was treated with 135 parts (92.5% alcohol) and 65 parts glycerol.

As stated in the recent research (11), separation of glycerides and fatty acids from high acid rice bran oil was effected by using ethyl alcohol as a solvent. The high acid rice bran oil was dissolved in rectified spirit and the resulting solution was cooled down. At this stage, the glycerides being less soluble in alcohol separated out from the solution as an oily layer. The fatty acid being soluble in alcohol remained in the solution. But fatty acid being soluble in glycerides, the separated oily layer may contain fatty acid as well.

In the deacidification of high acid rice bran oil, it has been observed that low acid layer was not well defined. When high acid crude rice bran oil containing a large proportion of non-glycerides and phosphatides was subjected to deacidification by fractionation in polar solvent, the glycerides portion failed to separate out from the layers of fatty acids in the solvent as reported in recent research work.(24) Separation of layers depend mostly on the property of solvent used in fractionation. Most glycerides are insoluble in polar solvent at room temperature whereas the fatty acids are readily soluble.(1)

Solubility of fatty acid in polar solvent increases with temperature and the ratio of solvent to fatty acid. Rice bran oil containing a large percentage of unsaturated fatty acids may probably be soluble even at the lower ratio of oil to alcohol. These polyunsaturated glycerides are liquid at normal temperature. This fact alone accounted for favourable separation of acid from glycerides at room temperature in polar solvents.

Veno (22) extracted free fatty acids from high acid rice bran oil with 75 - 80% ethanol. The oil to ethanol ratio of 1 : 4 was found to be appropriate. Rice bran oil with an acidity of AV 90 after four successive extractions with ethyl alcohol yields low acid value fraction with acidity less than AV 10.

As a result of evaluating these established facts and other literature references, it can be concluded that a substantial removal of free fatty acids from high acid rice bran oil by extraction with ethyl alcohol is technically possible.Previous workers (11,24) had failed to recognise the importance of non-fat constituents, gums and mucilages in the crude rice bran oil. The presence of these materials such as phosphatides and high melting waxes made separation difficult as evidenced in the alkali refining of fats and oils.

Under these circumstances, some important experimental works (23) on separation of low acid fraction from high acid rice bran oil were conducted in recent years with special emphasis on pretreatment processes such as prefilteration, degumming and dewaxing.

Many established works and publications in these areas provide ample information on the removal of non-fat components in the rice bran oil. Prefilteration of high acid rice bran oil in a plate and frame filter press at room temperature removes most of the silicious matters, dust, starches, proteinacious substances and waxes. These substances exist in suspension, colloidal and crystalline form. In the degumming process,hydratable and non-hydratable phosphatides present in the oil are removed. Water degumming (2.5% vol) at the temperature of 80 - 100°C, followed by treatment with concentrated phosphoric acids (0.1 to 0.3%) under the same temperature condition gave an excellent result. (Table 11,12) Dewaxing of prefiltered and degummed rice bran oil at 12°C for 3 hours by dry fractionation method (7) removed a

substantial quantity of high melting waxes.

The time-temperature variations, during chilling of the oil, provide a certain effect to control the size and stability of the wax crystals which in turn promote proper separation of waxes from the oil.

High acid rice bran oil with varying acidity ranging from AV 60 to AV 130 are subjected to fractionation in ethanol media. (Table 15) Appreciable reduction of acidity was achieved with the oil to alcohol ratio of 1 : 6 (volume).The validity of this process, in relation to low acid vegetable oil with acidity ranging from AV 12 - AV 37 was evaluated. (Table 16,17, 18) The multiple fractionation technique was also attempted and the results were very encouraging. (Table 19)

Overview of these established results on deacidification of high acid rice bran oil by fractionation in ethyl alcohol media provide a basis for formulating a commercially viable process. Technology relating to this newly developed process is too elaborate and the data are so numerous that only an important outline of the process is presented here as reference.

3.7 Decolorization by adsorption

Dissolved and suspended coloring matters and pigments in the oil are partially destroyed in the alkali refining stage. The remaining color bodies in the fats and oils are later removed in the adsorption-bleaching process. Varying quality of bleaching clays, earths and activated carbon are widely used in the vegetable and animal fats and oils processing industries.The choice of temperature at which the effective bleaching is possible, depend largely on the quality and mode of previous processing stage. The contact time and the agitation rate are also considered significant.

In atmospheric type decolorization, the agitation must be sufficient to keep the bleaching clay in suspension, but not so strong that air is mixed with the oil thereby causing oxidation of the oil. In vacuum bleaching operation, the effect of oxidation is negligible and agitation is usually more vigorous.(15) Temperature used for vacuum bleaching is much lower than atmospheric bleaching.

Removal of pigment from rice bran oil does not seem to have presented great problem despite this greenish color frequently reported. A number of studies indicate that conventionally earth bleaching will readily give oil with acceptable color for use as high grade cooking oil. Japanese practices currently involve adding 3 - 5% activated clay to rice bran oil at 60 - 80°C, heating to 100 - 110°C with agitation. The spent bleaching earth are later separated by filteration.

The selection of equipment is associated with the capacity of the plant. Continuous bleaching plants are designed for a bigger capacity refining complex. A small bleaching plant of 1 - 4 tons per batch or 4 to 10 tons oil per day are found in most commercial refining unit of batch design. Vacuum bleaching is preferable to atmospheric type. Bleaching of 4 tons per batch rice bran oil under partial vacuum of 100 - 200 mm Hg at 90-110°C requires 6 - 8 hours agitation. A stirring rate of 200 - 250 rpm is found appropriate. Atmospheric bleaching vessels with 1 ton per batch capacity requires 2 to 4 hours agitation at 90 - 100°C. An agitation rate of 100 - 200 rpm is practised in most commercial plants of batch design.

Acid activated clay from Japan, tonsil optimum from Belgium, Fuller's earth of ICI and activated carbon of varying grades are the common adsorbents widely used in the vegetable fats and oils industries, including rice bran oil for decolorization. Color measurements are conveniently carried out in 1" or

5¼" cell of the Lovibond Tintometer.

3.8 Deodorization by steam vacuum distillation

Vast differences in volatility between the glycerides and the substances which usually give oil and fat, their natural flavor and odor are the primary requirements for steam deodorization process. It is essentially a process of steam distillation wherein relatively volatile odourous and flavour substances are stripped of from relatively non-volatile glycerides.

The operation is carried out at high temperature to increase the volatility of the odorous components. Working under reduced atmosphere, protect oil from oxidation, prevent undue hydrolysis of the oil by the steam and greatly reduces the quantity of steam required. Deodorization also destroys any peroxides in the oil and removes aldehydes and other volatile products.(2)

In steam deodorization process, the bleached oil is first deaerted before feeding into the deodorizer. Air is evacuated from the vessel by vacuum, which was produced either by multiple steam ejectors system or a large capacity mechanical vacuum pump or the combination of both. The deaerated oil fed to the deodorizing vessel by means of suction are heated to 200 - 230°C, while the vacuum is also increased and maintained at 2-3 mm absolute. A live steam is injected at the same time to provide vigorous agitation of the oil in the vessel. Steaming during heating serves to degas the oil before it has become extremely hot.

If the oil is heated to a high temperature before it is thoroughly stripped of dissolved oxygen, interaction of oxygen and the oil will readily result with injury to the color and stability of the product. (2) In deodorizing a batch of oil, it

is preferable to maintain a full vacuum in the vessel and a flow of live steam during practically the whole of the heating period.

Gavin (4) modified the deodorization process of the oil to the maximum temperature of 180°C that is limited due to the detrimental effect on oil stability. Agitation of the oil to provide a high rate of heat transfer is accompanied by sparging with steam.Pressure and rate of sparging steam are limited by economic consideration. All deodorization pressure are conducted at high absolute vacuum of 2 - 3 mm Hg.

Deodorization of rice bran oil can be carried out in the normal manner by heating the oil to temperature of 200-250°C under high vacuum of 2 - 3 mm absolute, stripping out the volatile odorous matters, in a current of live dry steam. The deodorization time varies according to the capacity and the quality of feedstock. Typical rice bran oil deodorizing plant of batch design operates 4 to 8 hours for 4 tons batch of oil under the temperature and the degree of vacuum of 180°C and 8 - 10 mm absolute. Cooling under vacuum protect oil from oxidation at elevated temperature.

In a semi-continuous deodorizing vessel of horizontal tray type with a capacity of 700 litres per batch, the deodorization is carried out at 220 - 230°C and 2 - 3 mm absolute for 2 hours. Cooling under the same degree of vacuum is effected in a separate vessel of same capacity fitted with cooling coil.

The degree of vacuum is related to cooling water temperature in the barometric condenser of a vacuum apparatus operated on multiple steam ejectors system. The difference in colling water temperature between inlet and the outlet of barometric condenser in the order of 5 - 10°C is observed in the commercial deodorizing operation. The temperature measured at the

end of the barometric leg or hot well is an important data for process control purpose.

High temperature heating of oil in the deodorizer can be carried out in many different ways. The choice of a suitable heating system depend largely on the costs of the equipment. High pressure steam heating and the condensing vapor type chemical heating systems are widely used in the rice bran oil deodorization plants. Super-heated steam are also employed as a source of high temperature heating in the continuous deodorizing plants. Dowtherm or Thermax of varying grades are marketed as chemical heat transfer media. Dowtherm heating system or boiler is comparatively a low cost design, easier to operate and provide quick heating. Chemically, these fluids are known as Diphenyl-diphenyl oxides, a good heat transfer media of condensing vapor type.

A proper instrumentation is desirable for batch,semi-continuous or continuous deodorization plants.Temperature and vacuum gauges require calibration periodically for reliability and effectiveness in the measurement of the process data such as temperature, vacuum etc. Automatic recording devices are also employed for effective control of the process.

4. CONCLUSION AND RECOMMENDATION

Under the prevailing circumstances, the rice bran oil industries in South East Asia will continue to produce more high acid rice bran oil than much needed edible rice bran oil. The acidity of crude rice bran oil varies from AV 40 in the paddy season to over AV 70 in off season. If the extraction plants operate on rice bran which are transported to the plants within one to two months after milling, the average acidity of the bran could be controlled below AV 70. To improve production of more crude rice bran oil of low acidity, extraction of fresh rice bran,

parboiled rice bran and stablised rice bran should be effected within the stipulated storage period. Due to decrease in total extractable oil content of the bran during long storage, the extraction of old bran should be discouraged. It has been reported that reduction in total extractable oil content of milled rice and brown rice during storage was about 20 to 30% in 6months.

In addition to proper scheduling of these raw material resources, it is advisable to store rice bran after milling under low temperature condition in the rice mill, which has ample power, generated by husk, to produce cooling media, either by refrigeration or jet-vac cooling system. With the help of these pretreatment processes and thorough understanding of the nature of the raw materials, rice bran, under various stages of treatment, it is furvently believed that the crude rice bran oil can be made available for refining plant under relatively low free fatty acid content. The acidity of the crude rice bran oil,however, depend largely on effective management of these raw materials resources.

Although this system approach could not possibly keep the acidity of crude rice bran oil below AV 40 level, it can be made sure that the crude rice bran oil thus produced under effective management capability will be always below AV 70 or never beyond AV 70.

If these conditions are established, the rice bran oil produced in the extraction plants will be able to process for edible purpose. At this moment, the only technical problems will be the proper choice of refining process. It has been an accepted fact that the rice bran oil with AV 40 or less can be economically processed by alkali refining method. Crude rice bran oil with acidity more than AV 40, but not exceeding AV 70 - 80 can be processed by high acid oil refining method. If necessary, the combination of both alkali refining and fractionation should be

considered. Whether or not the crude rice bran oil is processed by alkali refining or any other known processes which is capable of handling high acid rice bran, pretreatment of crude rice bran oil is necessary for better separation of free fatty acid from the oil. Removal of gums and waxes are of primary importance.

Gums or phosphatides may be removed without much difficulty, but the separation of waxes seems to be a problem. In the development of a process on high acid oil refining by fractionation, effective methods of separating gums and waxes are discussed. Nevertheless, development of dewaxing process will be of some value for the processing of a good quality edible rice bran oil. Either alkali refining or single or multiple stage fractionation methods would be the choice for edible oil processing, it must be followed by decolorisation and deodorisation. A wide variety of adsorbents and methods of decolorisation are available for vegetable oil, including rice bran oil. Deodorisation equipments used in vegetable oil refining plant could be equally adaptable for rice bran oil as well.

It is therefore recommended that high acid rice bran oil refining by fractionation method should be explored for commercial application, in addition to alkali refining process. In order to achieve production of quality edible bran oil, necessary process control should be practised regardless of the acidity of the crude oil processed or the method used.

Table - 1 Change in Acidity of Milled Rice under Low Temperature Condition (9)

Sample - Ngakywe

Moisture Content - 11.0%

Acidity - AV 9.322

Storage (days)	% M/C	Temperature of Storage Atmosphere	
		- 15°C	+ 10°C
		Acidity (AV)	Acidity (AV)
32	11.4	8.43	12.203
62	11.8	8.929	16.973
93	11.3	9.312	19.643
122	11.2	10.085	21.166
152	11.8	9.842	23.678

Table - 2 Study on Growth of % FFA in freshly milled rice bran during storage under Room Temperature (13)

Time (Hrs)	Temperature (°C)	% FFA[a]	% R.H.[b]
9.00 A.M.	30	3.29	85
11.00 -	30	3.72	76
12.00 P.M.	30	4.51	76
13.00 -	30.5	4.44	73
14.00 -	30.5	4.53	73
15.00 -	30	4.70	74
16.00 -	30	4.99	74
17.00 -	30.5	5.40	73
18.00 -	30	5.95	75
19.00 -	30	6.30	75

(a) FFA = Free Fatty Acid

(b) R.H. = Relative Humidity

Table - 3 Study on Growth of % FFA in FRB[c] stored under Room Temperature (13)

Days (stored)	% FFA	% R.H.[b]	Temperature (°C)
1	3.29	95	30
2	8.90	80	32
3	11.90	85	30
4	15.84	83	29
5	18.38	83.5	29
6	22.22	83	29

(b) R.H = Relative Humidity

(c) FRB = Fresh Rice Bran

Table - 4 Growth of Acidity in Heat Stablized Bran (13)

Storage (days)	Sample B_1 (AV)	Sample B_2 (AV)	Sample B_3 (AV)
-	4.4	4.8	4.9
8	5.9	5.2	4.5
17	6.4	5.0	5.3
31	7.2	6.0	4.8
53	4.6	10.8	7.8
98	29.9	13.0	12.1

Table - 5 Growth of Acidity of Parboiled Bran obtained from pilot-scale processing of parboiled paddy under 48 hour steeping, 12 minutes steaming at steam pressure 60 psig (21)

Storage (days)	Moisture Content (%)	Acid Value (AV)
0	11.8	5.307
14	12.0	6.726
28	12.2	8.215
42	12.5	10.670
56	12.7	11.880
70	12.6	13.130
84	12.2	16.760
98	12.2	17.500
112	12.3	19.440
126	12.0	21.900
140	12.4	22.730
154	12.0	23.290
168	12.2	25.780
182	12.0	27.520
196	12.4	30.530
210	12.6	31.890
224	12.6	33.290

Table - 6 Growth of acidity of parboiled bran obtained from Henzada[(a)] during storage (21)

Storage Period (days)	Moisture Content (%)	Acid Value (AV)
0	9.6	6.077
7	9.8	6.400
14	10.0	8.087
21	10.4	10.310
28	11.6	13.290
35	13.0	16.880
42	13.4	18.020
49	13.4	24.310
56	13.4	28.270
63	13.8	31.390
70	14.4	44.920
77	14.8	51.960

(a) Henzada, location of the rice mill.

Table - 7 Growth of acidity of parboiled bran obtained from Kyauktaga[1] during storage (21)

Storage Period (days)	Moisture Content (%)	Acid Value (AV)
0	9.2	6.290
7	9.4	8.725
14	9.4	10.620
21	9.8	11.780
28	9.8	14.720
35	10.0	46.490
42	12.6	62.290

(1) Kyauktaga - location of the rice mill.

Table - 8 Increase in Acidity during storage in Winter (25)

Test No.	Date	Raw Rice Bran Temperature (°C)	Raw Rice Bran Moisture Content %	Raw Rice Bran Acid Value (AV)	FFA[a] Content (%)
1	1.21	1.2	13.2	19.59	9.79
2	22	9.2	12.7	22.02	11.01
3	23	9.1	13.0	22.15	11.07
4	25	6.6	13.4	23.42	11.71
5	26	6.1	13.2	23.82	11.91
6	27	5.8	13.2	25.40	12.70
7	28	5.8	12.3	25.91	12.95
8	29	5.4	12.8	26.25	13.12
9	30	5.1	12.5	26.71	13.35
10	2. 1	4.9	13.0	27.41	13.70
11	2	4.5	12.6	30.49	15.24
12	3	4.6	12.2	29.86	14.83
13	4	4.9	12.7	31.00	15.50
14	5	5.1	12.8	30.04	15.02
15	6	5.4	12.2	29.01	14.50
16	8	5.5	12.2	32.22	16.11
17	9	5.5	12.0	32.30	16.15
18	10	5.4	12.0	33.14	16.57
19	12	5.5	12.6	37.08	18.54
20	13	5.4	12.4	36.02	18.01
21	15	6.3	12.2	38.12	19.06
22	16	6.3	12.0	40.93	20.46
23	17	6.6	12.0	41.16	20.58
24	18	6.0	11.2	40.45	20.22
25	19	5.8	11.6	39.13	19.56
26	20	6.0	11.6	38.27	19.13

(a) FFA = Free fatty acids

Table - 9 Decrease in Total Extractable Oil Content of Brown Rice during storage (9)

Sample - Shwe War Tun

Storage - May to December

Storage (days)	Relative Humidity	Moisture Content % (wt)	Total Oil Content (mfb) [1] % (wt)
30	85	12.4	2.111
60	90	14.4	2.124
90	90	14.2	2.063
120	85	11.9	2.039
150	80	14.3	1.795
180	70	15.4	1.884
210	69	18.6	1.149

(1) mfb = moisture free basis

Table - 10 Decrease in Surface Fat Content of Ngakywe type Milled rice during storage (9)

Milled rice sample - Ngakywe

Period of storage - Aug to Jan.

Period of storage (days)	Relative Humidity (%)	Moisture Content % (wt)	SFC (mfb)[a] % (wt)
9	89	10.2	0.824
39	87	14.4	0.591
69	63	10.4	0.364
99	57	12.4	0.363
129	55	12.7	0.351

(a) mfb = moisture free basis

Table - 11 Degumming by Hydration with different amount of Water (23)

Sample - Partially[1] degummed crude rice bran oil
Preheated temp.(°C) - 90
Agitation time (hour)- 1
Agitation rate (rpm) - 800
Volume of sample(ml) - 50
Temp of hot water(°C)- 100

	Percent volume of hot water				
	(1.0)	(1.5)	(2.0)	(2.5)	(3.0)
Volume of gum (ml)	0.43	0.45	0.46	0.47	0.33
Percent yield of gum (vol)	0.86	0.90	0.92	0.94	0.66
Acidity (AV)					
Before degumming	81.53	81.53	81.53	81.53	81.53
After degumming	82.08	82.34	82.43	83.06	81.66

(1) Partially degummed - degummed with 0.1% Concentrated phosphoric acid

Table - 12 Degumming of Prefiltered[a] Crude Rice Bran Oil using different concentrations of Concentrated Phosphoric Acid (23)

Preheated temperature (°C) - 90
Agitation time (hour) - 1
Agitation rate (rpm) - 800
Volume of sample (ml) - 50

Concentration of concentrated phosphoric acid	Percentage					
	(0.1)	(0.2)	(0.3)	(0.4)	(0.5)	(0.6)
Volume of gum(ml)	0.60	0.61	0.64	0.65	0.66	0.68
percent yield of gum (vol)	1.20	1.22	1.28	1.30	1.32	1.36
Acidity (AV)						
Before degumming	76.19	76.19	76.19	76.19	76.19	76.19
After degumming	78.93	79.18	80.19	80.39	81.33	81.53

(a) Prefiltered - filtration at room temperature

Table - 13 Winterization of Fully Degummed[1] Crude Rice Bran Oil at 12°C (23)

Preheated temperature (°C) - 70

Agitation time (hour) - 3

Agitation rate (rpm) - 300

Volume of sample (ml) - 50

Run No.	1	2	3	4	5
Volume of wax (ml)	9.0	8.5	9.0	8.5	9.0
Percent yield of wax (vol)	18.0	17.0	18.0	17.0	18.0
Acidity (AV)					
Before Winterization	83.06	83.06	83.06	83.06	83.06
After Winterization	86.66	86.75	86.82	87.03	86.62

(1) Fully degummed - treated with 0.6% (vol) conc. Phosphoric acid and 2.5% (vol) of water.

Table - 14 Recovery and yield in different stages of Refining Crude Rice Bran Oil (27)

Description	Unit	Batch No.		
		1	2	3
Initial lot of CRBO	Kilo	15,652	17,148	15,672
Acidity	% FFA	5.00	9.50	12.54
First Refining	Kilo	13,278	14,897	11,767
Second Refining	Kilo	13,061	-	-
After Washing	Kilo	12,864	12,954	n.a.
After Bleaching & Deodorization	Kilo	11,546	10,943	10,425
After Winterization & dewaxing	Kilo	10,732	10,439	9,500
Edible oil yield	%	68.57	60.88	60.62
Acidity of Edible Oil	% FFA	0.25	0.392	0.33

n.a. = not available

Table - 15 Separation of LAV Fraction from Fully Pretreated[1] HAV Crude Rice Bran Oil by Fractional Crystallization in Solvent Media (23)

Preheated temperature (°C)	- 70
Agitation time (hour)	- 1
Agitation rate (rpm)	- 300
Solvent	- 95% Ethyl alcohol
Volume of sample (ml)	- 30
Ratio of oil to solvent	- 1 : 6

	Acidity of sample (AV)			
	59.69	73.44	108.27	127.09
Volume of LAV oil (ml-sfb)	19.49	19.54	12.99	3.78
Percent yield (vol)	68.3	65.3	43.3	12.60
Acidity (AV)	17.09	19.62	26.01	39.78
Volume of HAV oil (ml-sfb)	7.98	9.99	15.46	24.99
Percent yield (vol)	26.6	33.3	51.6	83.3
Acidity (AV)	120.66	130.4	181.5	179.3

(1) Fully pretreated - treated with 0.1% conc. phosphoric acid, 2.5% (vol) water and dewaxed at 12°C for 3 hours.

Table - 16 Deacidification of Fully Pretreated[a] LAV Crude Peanut Oil under Varying Acidity Range by Multiple Fractional Crystallization (23)

Preheated temperature (°C) - 70

Agitation time (min) - 30

Agitation rate (rpm) - 1100

Solvent - 95% Ethyl alcohol

Actual volume of sample (ml) - 30

Ratio of oil to solvent - 1 : 6

Run No.	Fractionation	Sample		LAV fraction recovered		
		Volume (ml-sfb)	Acidity (AV)	Volume (ml-sfb)	Acidity (AV)	Percent yield (vol)
1.1	First	100.0	13.62	75.0	1.42	75.0
2.1	First	100.0	23.55	60.0	1.83	60.0
3.1	First	100.0	33.42	60.0	6.27	60.0
3.2	Second	60.0	6.27	55.0	1.56	55.0

(a) Fully Pretreated - treated with 0.1% Conc.Phosphoric acid, 2.5% water and dewaxed at 12°C for 3 hours.

Table - 17 Deacidification of Fully Pretreated[1] LAV Crude Sesame Oil under Varying Acidity Range by Multiple Fractional Crystallization (23)

Preheated temperature (°C) - 70

Agitation time (min) - 30

Agitation rate (rpm) - 1100

Solvent - 95% Ethyl alcohol

Actual volume of sample (ml) - 30

Ratio of oil to solvent - 1 : 6

Run No.	Fractionation	Sample		LAV fraction recovered		
		Volume (ml-sfb)	Acidity (AV)	Volume (ml-sfb)	Acidity (AV)	Percent yield (vol)
1.1	First	100.0	12.6	80.0	1.28	80.0
1.1	First	100.0	24.8	68.0	1.72	68.0
3.1	First	100.0	33.9	70.0	7.28	70.0
3.2	Second	70.0	7.28	64.0	1.52	64.0

(1) Fully pretreated sample - pretreated with 0.1% Conc. phosphoric acid, 2.5% water and dewaxed at 12°C for 3 hours.

Table - 18 Deacidification of Fully Pretreated[(a)] LAV Crude Rice Bran Oil under Varying Acidity Range by Multiple Fractional Crystallization (23)

Preheated temperature (°C) - 70

Agitation time (min) - 30

Agitation rate (rpm) - 1100

Solvent - 95% Ethyl alcohol

Actual volume of sample (ml) - 30

Ratio of oil to solvent - 1 : 6

Run No.	Fractionation	Sample		LAV fraction recovered		
		Volume (ml-sfb)	Acidity (AV)	Volume (ml-sfb)	Acidity (AV)	Percent yield (vol)
1.1	First	100.0	12.68	73.0	1.20	73.0
2.1	First	100.0	21.31	71.8	1.23	71.8
3.1	First	100.0	36.43	70.5	6.47	70.5
3.2	Second	70.5	6.47	68.21	1.32	68.21

(a) Fully pretreated - treated with 0.1% Conc. Phosphoric acid, 2.5% (vol) water and dewaxed at 12°C for 3 hours.

Table - 19 Deacidification of Fully Pretreated[(a)] HAV Crude Rice Bran Oil under Varying Acidity Range by Multiple Fractional Crystallization (23)

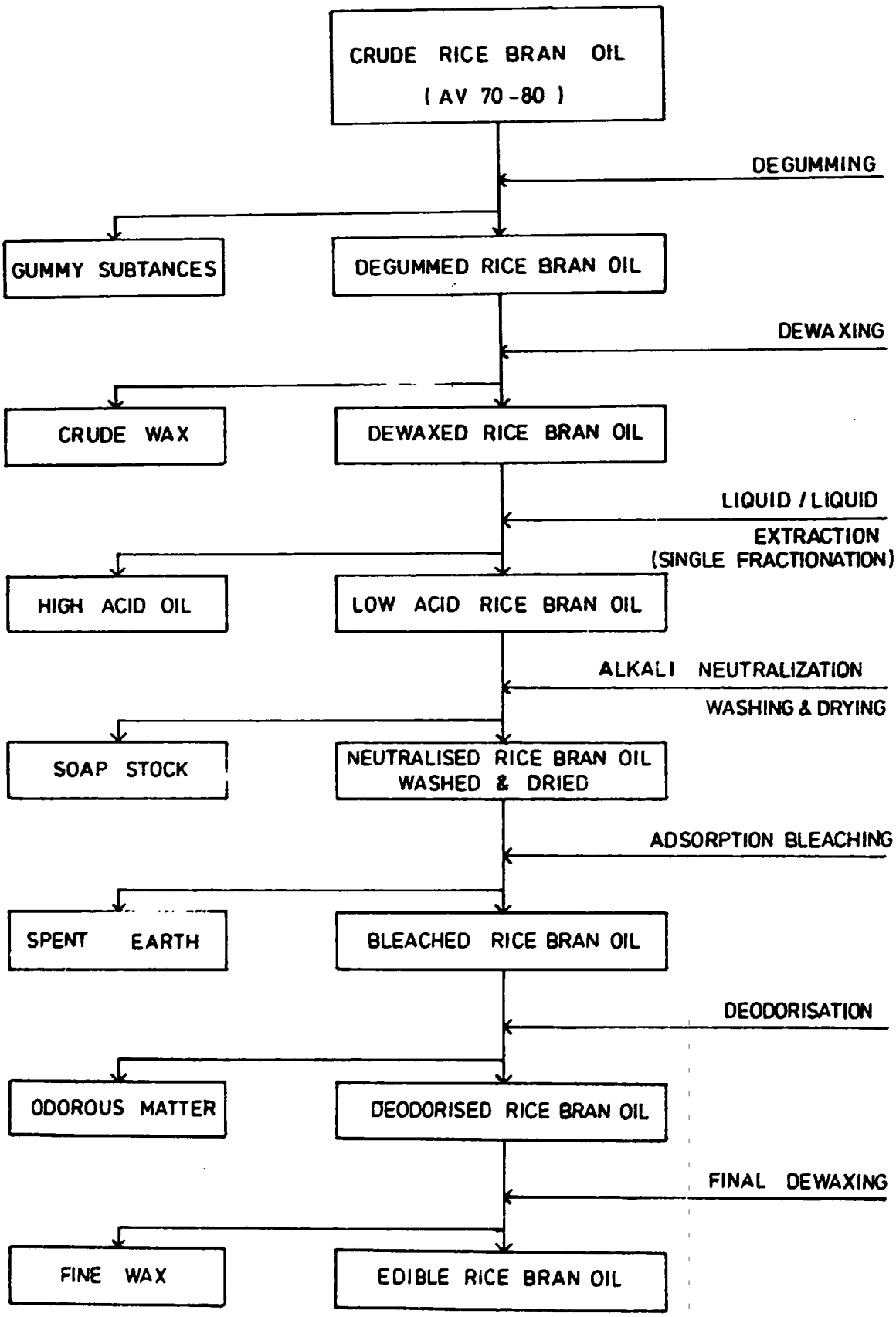
Preheated temperature (°C) - 70
Agitation time (min) - 30
Agitation rate (rpm) - 1100
Solvent - 95% Ethyl alcohol
Actual volume of sample (ml) - 30
Ratio of oil to solvent - 1 : 6

Run No.	Fractionation	Sample		LAV fraction recovered		
		Volume (ml-sfb)	Acidity (AV)	Volume (ml-sfb)	Acidity (AV)	Percent yield (vol)
1.1	First	100.0	48.22	68.22	9.32	68.22
1.2	Second	68.22	9.32	65.00	1.88	65.00
2.1	First	100.0	53.68	65.0	12.68	65.0
2.2	Second	65.0	12.68	62.0	6.56	62.0
2.3	Third	62.0	6.56	60.0	1.56	60.0
3.1	First	100.0	62.78	62.0	13.23	60.0
3.2	Second	62.0	13.23	58.0	7.23	58.0
3.3	Third	58.0	7.28	57.0	1.72	57.0
4.1	First	100.0	71.65	58.0	16.28	58.0
4.2	Second	58.0	16.28	57.0	8.62	57.0
4.3	Third	57.0	8.62	54.0	1.82	54.0

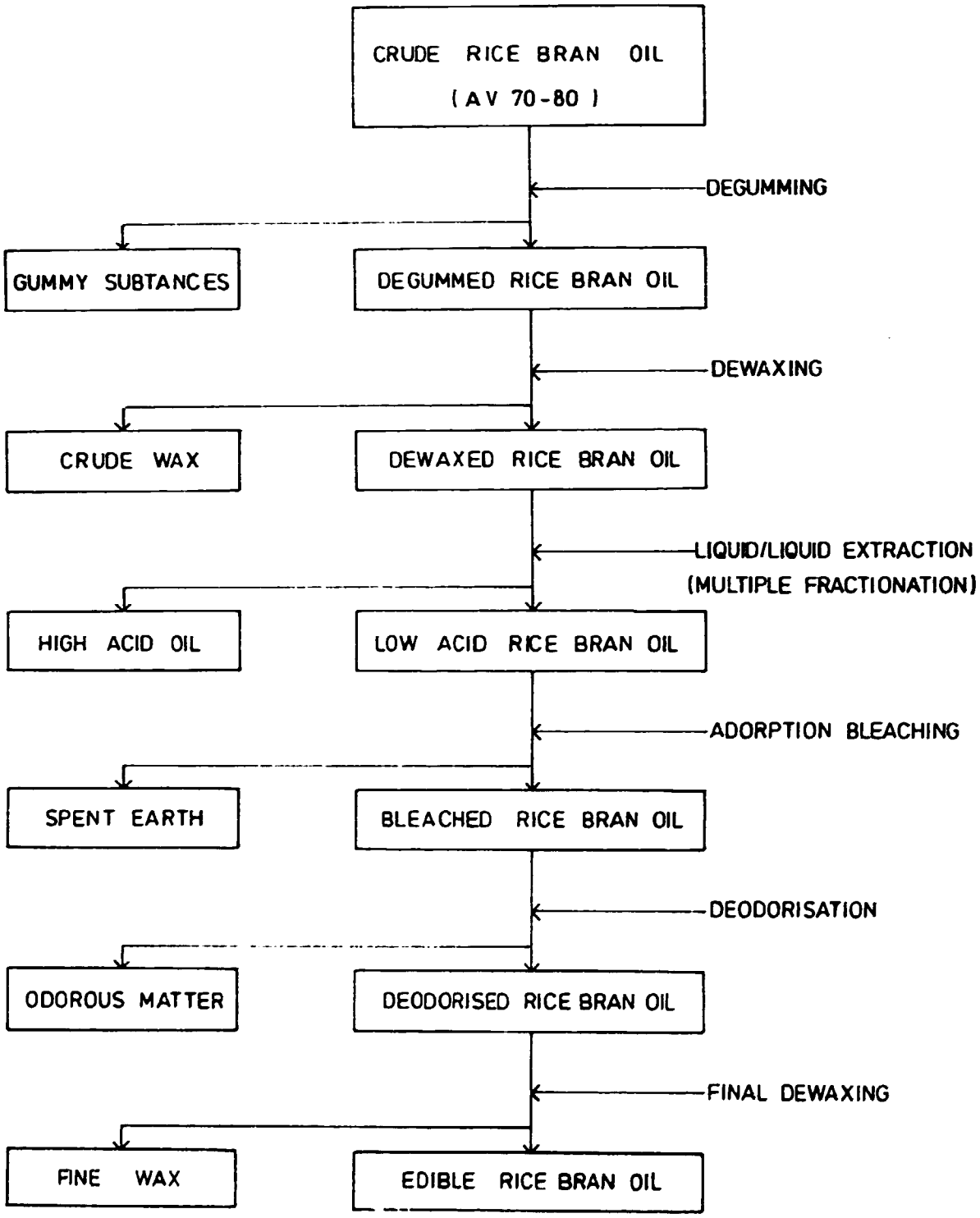
(a) Fully pretreated - treated with 0.1% Conc. phosphoric acid, 2.5% water and dewaxed at 12°C for 3 hours.

Appendix - A

I . Refining Process - (A)

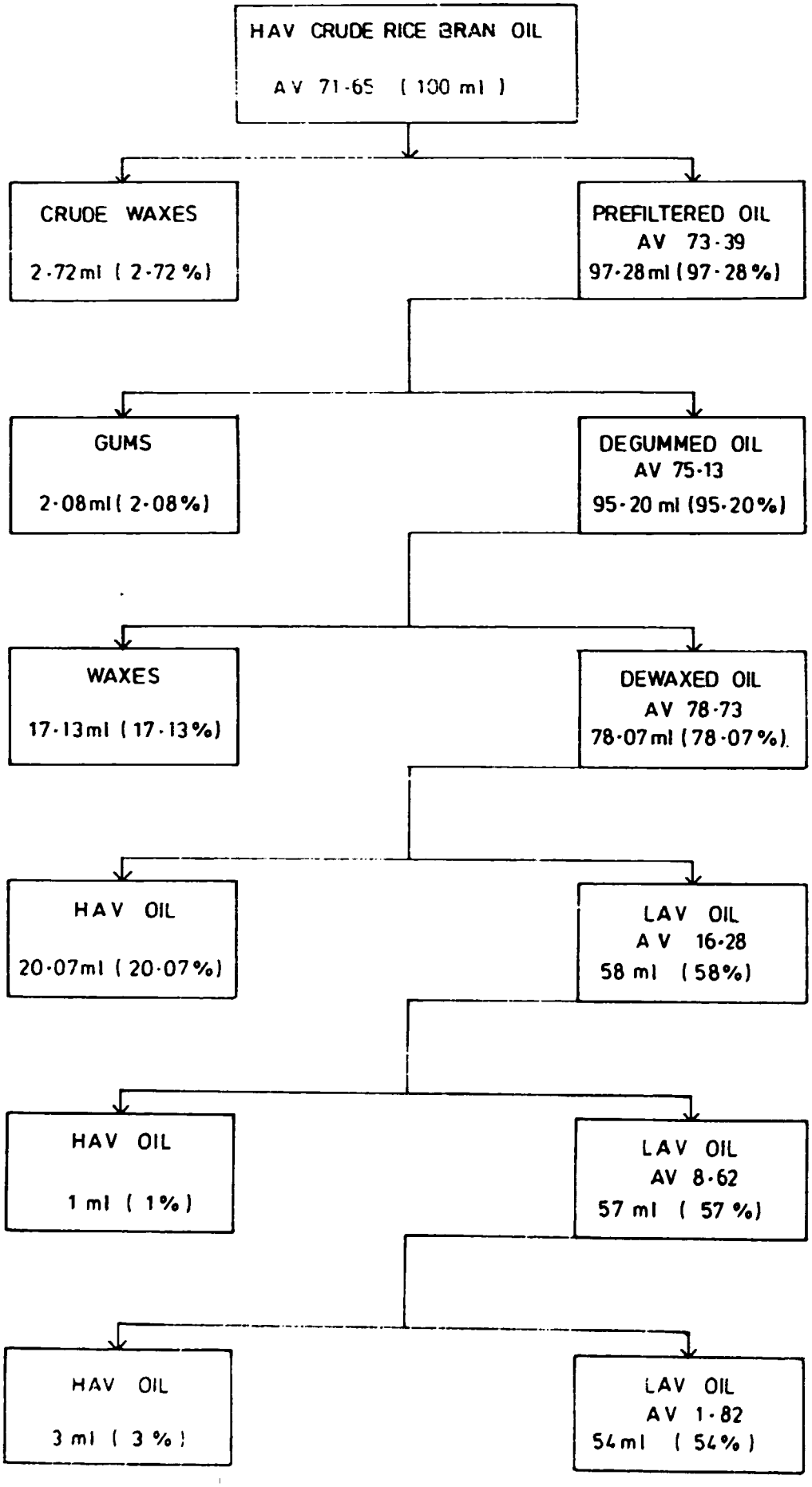


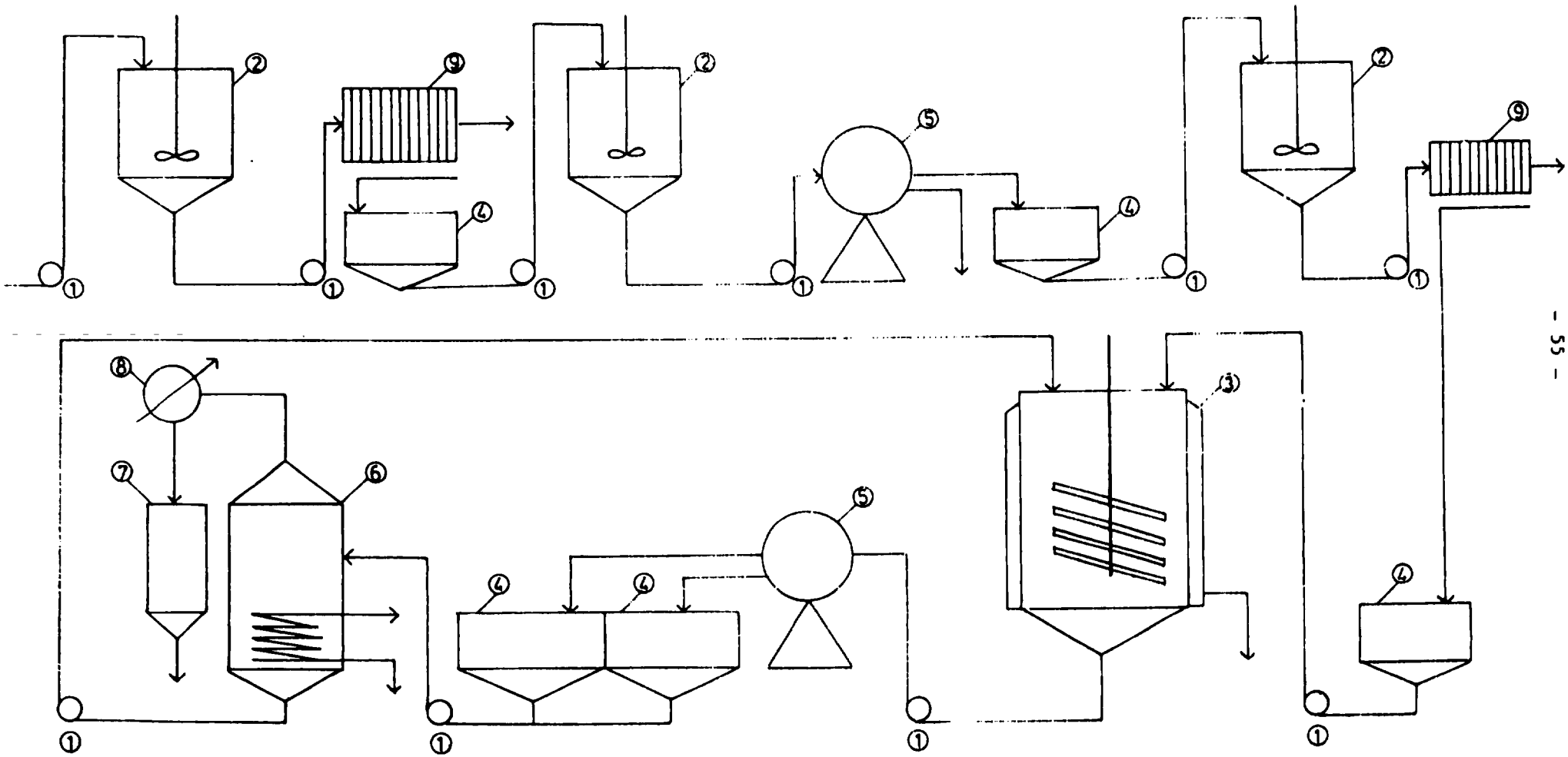
II. Refining Process - (B)



Appendix - C

III . Material Flow Chart





IV. FLOW DIAGRAM FOR DEACIDIFICATION BY FRACTIONATION

1. PUMPS
2. MIXING TANKS
3. CRYSTALLISER
4. TANKS (STORAGE)
5. CENTRIFUGE
6. DISTILLATOR
7. SOLVENT RECEIVER
8. CONDENSING SYSTEM
9. FILTER PRESS

BIBLIOGRAPHY

1. Baily, A.E. — Melting and Solidification of Fats, Interscience Publishers Inc 20, 43, 343-5, 516 (1950)
2. Baily, A.E. — Ind. Oil and Fats Product, 2nd Ed. Interscience Publishers Inc.20-28, New York (1951)
3. Carr, R.A. — Refining and Degumming System for Edible Oil and Fats, JAOCS,55,765 (1978)
4. Gavin, A.M. — JAOCS, 58, 177 (1981)
5. Gutfinger, T. — Pretreatment of Soybean Oil for Physical Refining, JAOCS, 55, 856 (1978)
6. Harris, R.V. — Rice Bran Oil and Waxes, ID/WG 89/8 UNIDO, 20, 25 Feb 1971
7. Hla, P.K. — Process Development for effective Dewaxing of Edible Rice Bran Oil, M.Sc. Thesis, (Ind. Chem.) Rangoon Univ (1982)
8. Kirchenbauer, H.G. — Fats and Oils, An Outline of their Chemistry and Technology Reinhold Publishing Corp. New York (1944)
9. Kyi, Z.Z. — Evaluation on Milling Degree of Rice and Deteriorative Changes of Rice during Storage, M.Sc. Thesis, (Ind. Chem.) Rangoon Univ. (1984)
10. Mounts, T.L. — JAOCS, 58, 514 (1981)

11. Myint, D.S. — Refining of Rice Bran Oil with Ethyl Alcohol as Selective Solvent, M.Sc. Thesis (Chem.) Rangoon Univ. (1973)

12. Pandurang, M.S. — Country Paper (India) Expert Group Meeting on Down Stream Processing Activities in the Vegetable Oils and Fats Industry, Vienna 8 Feb. (1984)

13. Pe, U.M. — Study on Stablization of Rice Bran Oil and Its Storage Ability, U.B.J. of Sci. and Tech. Vol V, No.1 Feb. (1972)

14. Richardson, L.L. — JAOCS 55 , 777 (1978)

15. Ringers, H.J. — United States Patent, 4, 049, 686, Sept. 20, (1977)

16. Rothe, M. — Inactivation of Enzymes, International Problem of Modern Cereal Processing and Chemistry, Bugholz-Rehbrucks, Jan, (1967)

17. Schwitzer, M.K. — Margarine and other Food Fats, Leonard Hill (Books) Ltd., London (1956)

18. Sullivan, F.E. — Reviewer's Comments on Steam Refined Soybean Oil, JAOCS, J3006/7, Sept, 12 (1977)

19. Sullivan, F.E. — Steam Refining, JAOCS, 53,358 (1976)

20. Takishita, Y. — Technical Advances in Rice Bran Oil Processing ID/WG 89/5 - UNIDO, 28 Jan (1971)

21. Thein, K.S. Effect of Steeping Time, Steaming Time and Steam Pressure During Parboiling of Paddy on the Stablity of Parboiled Rice Bran, M.Sc.Thesis (Ind.Chem.) Rangoon Univ. (1982)

22. Veno, I.S. J.Agr. Chem. Soc. Japan vol. 19, 940-3 (1943)

23. Win, K.K. Separation of Edible Oil from High Acid Crude Rice Bran Oil by fractional crystallization, M.Sc. Thesis, (Ind.Chem.) Rangoon Univ. (1984)

24. Win, U.T. Solvent Refining of High Acid Rice Bran Oil, M.Sc. Thesis (Chem.) Rangoon Univ. (1975)

25. Yokochi, K. Rice Bran Processing for the Production of Rice Bran Oil and Rice Bran Protein Meal, Rice Bran Oil Technological Res. Inst. Tokyo, Japan p.47 - 50.

26. Directory of U.S. Rice Mills, The Rice Journal, 46 - 50, July - Aug (1977)

27. Development of Rice Bran Oil Technology In Philippines, RAPA 51, FAO, Bangkok, Thailand

28. Gemeinschaftsarbeiten der DGF, 77, Mitteilung, Fette, seifen, Anstrichm. 83, 39 (1981)