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

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Interregional Seminar on the
Industrial Processing of Rice

SUMMARY

UTILIZATION OF RICE BRAN [1]

by

D. Halliday
Tropical Products Institute
London, United Kingdom

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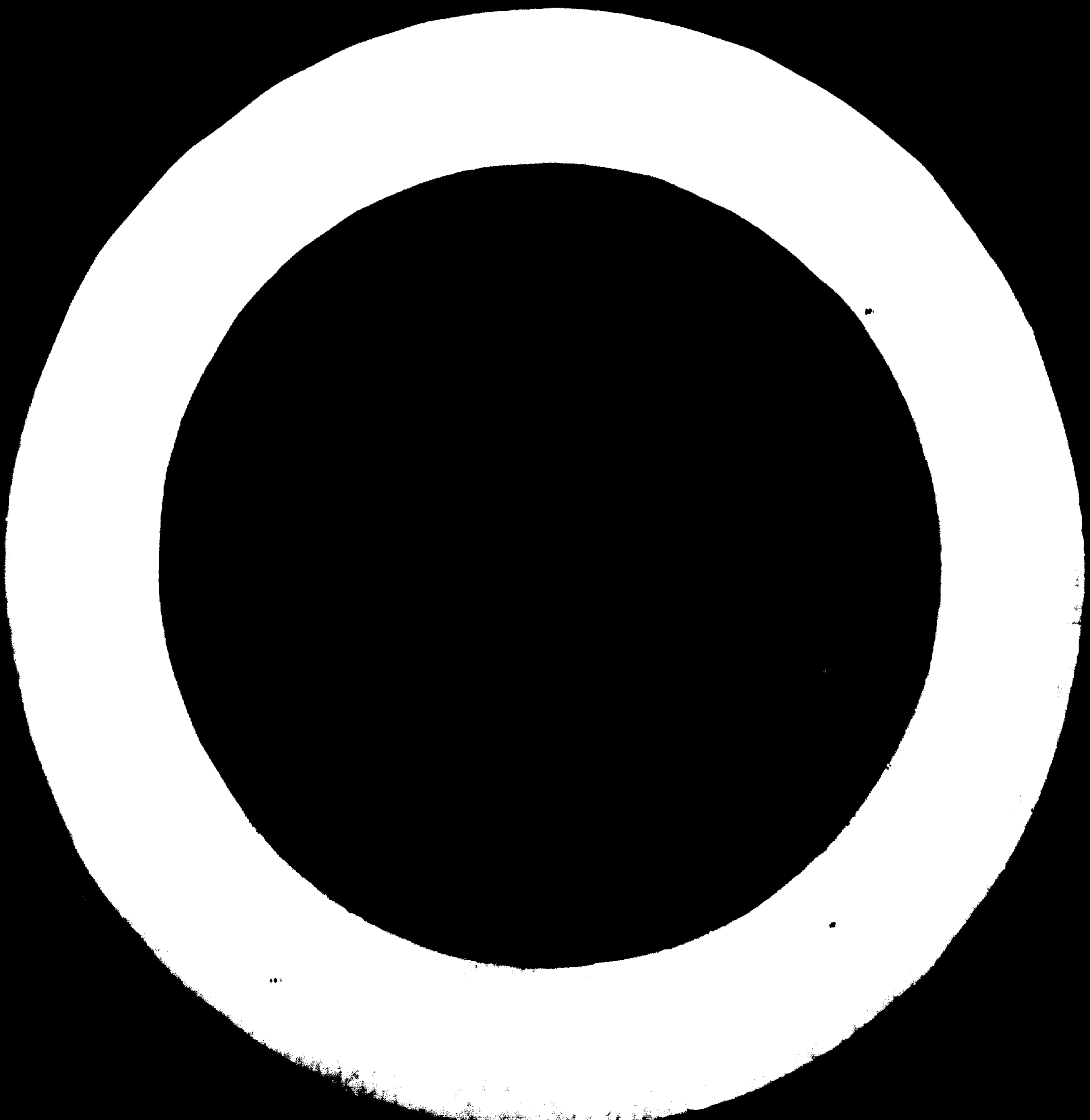

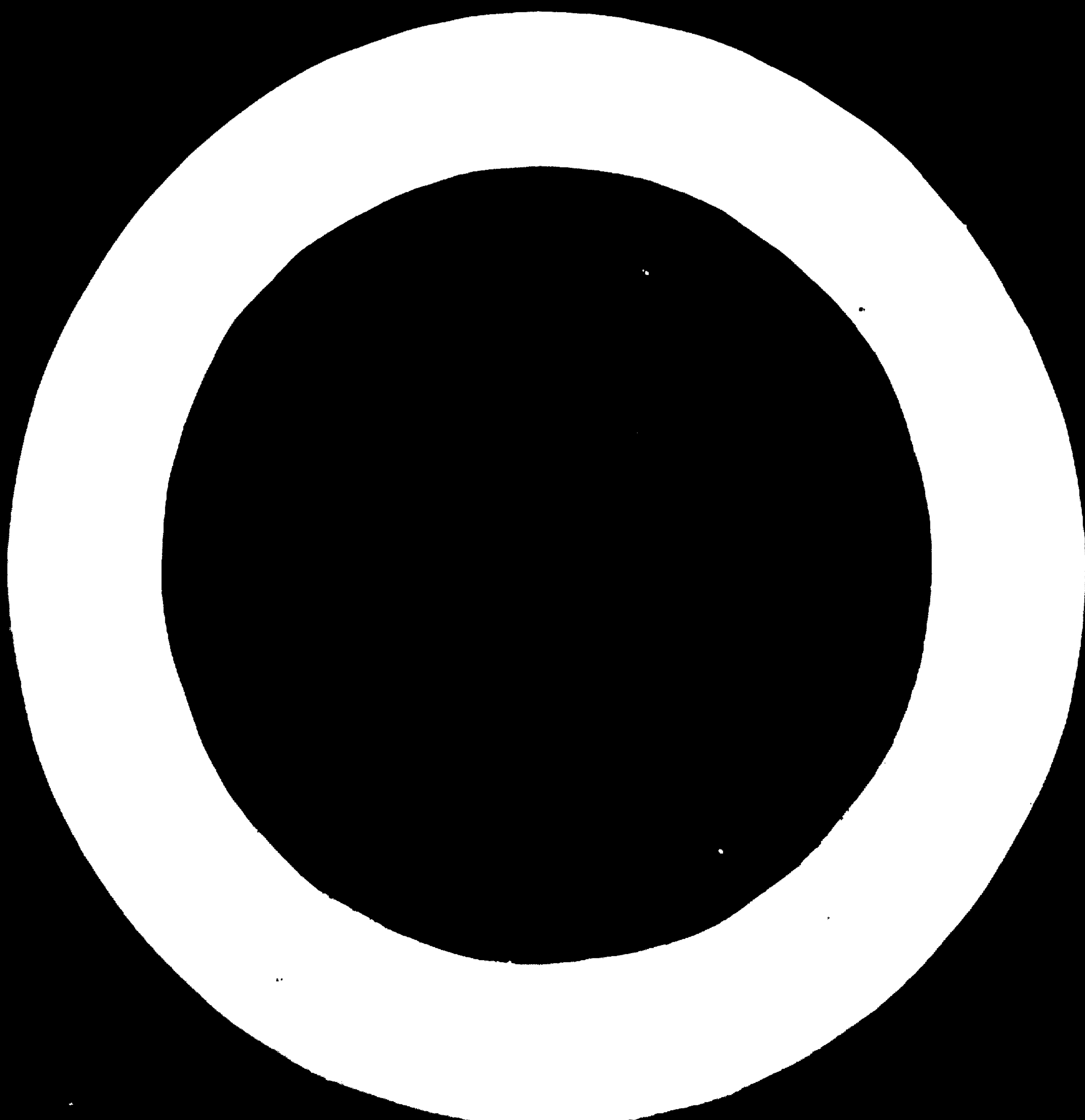

1. This paper surveys the potential production, composition, properties, and current and possible utilisation of rice bran with particular reference to the South-East Asia/Far East Region.

Production

2. The potential world production of rice bran and polish is assessed at between 28 and 29 million tons per annum, of which over 90 per cent is produced in the South-East Asia/Far East Region. The two largest producers are mainland China and India.

Milling, Bran Composition and Properties.

3. The three products of milling are bran, polish and husk. Bran, which includes the germ, accounts for 8 per cent, polish 2 per cent and husk 20 per cent by weight of the unprocessed paddy. It is only in large rice mills that the components can be completely separated, and much bran is contaminated with husk.

4. Bran contains 15-18 per cent of oil, which is subject to rapid lipolysis unless stabilised by steaming or otherwise. Bran from parboiled rice is more stable.

Rice Bran as a Source of Edible Oil.

5. Rice oil is roughly equivalent in properties to cottonseed or maize oil. Current world production is only some 150,000 tons per annum, despite a much greater potential in terms of raw material resources. Japan is the largest producer with an annual production of some 90,000 tons.

6. The difficulties of expanding production are related to the small size of many rice mills, making it difficult to collect sufficient fresh or stabilised bran to support an economic scale of production.

7. Rice oil is prepared by solvent extraction of bran with hexane. The smallest economic unit would process 25 tons per hour.

Rice Bran as Animal Feed.

8. Rice bran is currently almost exclusively used as animal feed. It contains 12-14 per cent crude protein and around 12 per cent crude fibre. Rice bran protein is richer in lysine than that of milled rice, and rice bran is also richer in B

vitamins and minerals. The energy content of defatted rice bran is about equivalent to that of wheat bran, and can be used as a replacement for part of the cereals normally incorporated in concentrate rations. Admixture with husk impairs feed value especially for monogastric animals. Rice polish is low in fibre (2-3 per cent) and thus more suitable for feeding to monogastric animals.

9. The oil of bran should be stabilised or extracted due to the possible adverse effect of rancidity on palatability.

Export Potential for Rice Bran as Animal Feed.

10. Assuming that compositional standards are maintained, there is no reason why rice bran should not be exported as animal feed. Care will be needed to avoid rancidity problems. Extracted rice bran should command a price similar to that of wheat bran.

Potential Use of Rice Bran and Polish as Food.

11. The vast amounts of rice bran and polish at present fed to animals, represent a source of protein which could perhaps be exploited to improve the protein deficient diets of the developing countries of the Far East. This is especially so taking into account the high lysine content of rice bran protein. The high vitamin B content also has considerable nutritional advantages.

12. Processes have been developed for producing edible bran by reducing fibre content and ways have been suggested of incorporating them in food products. Protein concentrates can also be made by techniques based on alkaline solubilisation, and imitation milks can be made from them.

13. Protein foods containing rice bran and protein concentrate have not found any great acceptance as yet, and their exploitation will be difficult under current conditions.

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UTILIZATION OF RICE BRAN [1]

by

D. Halliday
Tropical Products Institute
London, United Kingdom

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CONTENTS

Introduction.

1. Rice is by far the most important cereal grown in South-East Asia and the Far East. In 1969-70 annual production of rice in the region (expressed as milled rice) was estimated at 182,135,000 tons, of which 94,000,000 tons and 59,649,000 tons were produced in mainland China and India respectively. Production in South-East Asia and the Far East constituted some 91 per cent of a total estimated 1969-70 world production of 200,550,000 tons of milled rice (Anon, 1970 a).

2. When paddy is processed into milled rice 30-35 per cent by weight is lost as by-products, of which about one third is represented by bran and polish and two thirds by husk. If all the rice produced in the South-East Asia/Far East region were processed into milled rice a minimum of 26,019,000 tons of bran and polish would have been produced in 1969-70. This is by any reckoning a massive raw material source, and its effective utilisation is of vital importance.

3. Statistics for the estimated production of rice and its by-products during 1969-70 are given in Table 1 below.

Table 1

Estimated Rice Production 1969-70 in Different World Regions
(Anon, 1970 a)

Region	Production (Thousands of Tons)			
	Paddy	Milled Rice	Husk	Bran and Polish
S.E. Asia/Far East	260,193	182,135	52,039	26,019
North and South America	12,914	9,040	2,583	1,291
Middle and Near East	3,730	2,611	746	373
Africa, South of Sahara	2,793	1,955	559	279
Western and Southern Europe	1,610	1,127	322	161
Soviet Union	1,500	1,050	300	150
Miscellaneous	3,760	2,632	752	376
Total	286,500	200,550	57,301	28,649

4. Production figures for milled rice, husk and bran and polish have been calculated from those given for paddy, on the basis of respective yields of 70, 20 and 10 per cent, and should not, therefore, be taken as actual production.

Milling, Bran Composition and Properties.

5. Rice differs markedly in structure from other common cereals, making it necessary to use a specialised method of processing into an edible form. Paddy has a hard fibrous outer husk to which the grain itself is attached. The husks constitute about 20 per cent by weight of the paddy, and are unsuitable for feeding even to ruminant animals because of high silica content and their abrasive nature.

6. The kernel inside the outer husk is covered with the so-called "Pericarp" or "Bran" layers, which are the remains of the ovary walls. These are removed during the first stage of milling dehusked rice together with the seed embryo, and the two together form the rice bran of commerce. Under the pericarp layers lie the so-called "Aleurone" layers, which are removed in the final stage of milling, and which are generally referred to as polish. The starchy core remaining after removal of the pericarp and aleurone layers and the germ is referred to as milled rice. In efficient mills yields of about 8 per cent of bran (including germ) and 2 per cent of polish may be expected.

7. In the larger rice mills, processing is carried out in three stages viz. husking, milling and polishing, so that it is possible to collect each by-product separately. In smaller mills, however, the operation may be in two stages, the polishing and milling being carried out together. In the smallest mills all three operations may be carried out together. In such mills it will obviously be difficult to separate the three by-products so as to market them individually. Details of techniques and machinery used for the conventional processing of rice are given elsewhere (Aten et al, 1958). Husking is normally carried out by passing paddy between two horizontal discs of stone or cast iron, coated on their facing surfaces with a composition of emery and cement, one of which is stationary while the other revolves. Other huskers developed in more recent years include those based on the principle of passing paddy between horizontal rubber rollers revolving at different speeds. Milling is traditionally carried out by scouring husked rice in "Whitening Cones". These are vertical truncated cones covered with a mixture of emery and cement, revolving inside a steel wire screen. Husked rice enters at the top and is rubbed between the cone and the screen before being released at the bottom, the amount of scouring being controlled by raising or lowering the cone. To minimise breakage, rice is normally passed through a battery of cones in the larger mills. Final polishing may be carried out using cones made from wire cloth mounted on a wooden frame, or by passing between a series of rollers or drums covered with a material such as sheepskin and encased in a fine wire mesh. Other types of whitening machines include those based on the principle of "Tamping" and the more recently developed "Groover Rotor Whitening Machine".

8. As the germ, and pericarp and aleurone layers contain most of the oil of rice kernels, bran and polish are very rich in oil compared with husked or milled rice. Bran and polish are also richer in minerals, protein and B. group vitamins for

similar reasons. As the pericarp is fibrous in nature, bran has a higher fibre content than husked or milled rice, or polish. Figures given in the literature for the proximate composition of rice and its by-products are given in Table 2 below.

Table 2

Composition of Rice and its By-Products

Material	Proximate Composition (Dry Basis), per cent				
	Crude Protein (NX6.25)	Oil	Crude Fibre	Ash	Nitrogen Free Extract
Husked Rice	10.4	2.3	1.3	1.3	84.7
Milled Rice	8.5	0.5	0.5	0.6	89.9
Husk	3.3	0.9	44.2	21.5	30.1
Bran	13.6	15.0	12.8	14.6	44.0
Polish	14.2	14.9	3.0	11.0	56.9

9. The composition of milled rice and its by-products will depend very greatly on initial composition and the milling techniques employed, and figures given in the literature can only be taken as a very general guide to what may be expected. It is difficult to separate husk, bran and polish completely in all but the most efficient plants, and some admixture with small pieces of broken milled rice is also likely. For the smaller less efficient mills, therefore, the by-products are likely to be marketed as different grades of mixtures containing various proportions of husk, bran, polish and small pieces of milled rice. A good example of this is given by Limangoo-Lopes et al (1962), who made a survey of the composition of rice by-products produced in the islands of Luzon and Mindanao in the Philippines. Three grades of rice bran from cone mills (fine, coarse and bran-husk mixture) and two grades from husker rice mills (fine bran-husk and coarse bran-husk mixtures) were identified. However, it was pointed out that even this classification was arbitrary and very dependant on the rice mill operator. Evidence was also produced of variations in composition of by-products, which could be attributed to the variety of rice milled and the locality in which it was grown.

10. The high oil content of bran and polish raises problems with regard to stability. Naturally occurring enzymes liberated during the milling process cause rapid hydrolysis of the oil of rice bran as measured by free fatty acid increase. This hydrolysis (or "Lipolysis") is very rapid, and it has been reported that the free fatty acid content of the oil may increase from about 3 per cent in fresh bran at the rate of 1 per cent per hour during the first few hours after milling.

reaching about 60-70 per cent within a month (Murti and Rao, 1951). Lipolysis causes untreated bran to develop an unpleasant rancid odour and flavour during quite short storage periods.

11. Rate of lipolysis in bran is dependant on moisture content and storage temperature. Drying to moisture contents of less than 4 per cent will retard but not stop lipolysis completely, while storage at low temperatures will also reduce lipase activity (Loeb et al, 1949). Gas plasma irradiation has also been reported to inhibit lipolysis (Roseman et al, 1963). However, the best methods of limiting lipolysis in fresh bran from a commercial standpoint are the removal of the oil by solvent extraction, and/or the inactivation of the lipolytic enzymes (lipases) by steam treatment. In the latter connection it has been shown that steaming at temperatures slightly in excess of 100 degrees C inactivates the lipases within 5-10 minutes (Lynn, 1969). Dry heating at 110 degrees C for a period of 2 hours also inhibits lipolysis effectively by both inactivating the lipases and reducing moisture content (Loeb et al, 1949).

12. Parboiling of paddy before milling by soaking, steaming and drying, using either the traditional methods or the more sophisticated procedures developed in the USA (Aten et al, 1958), would be expected to affect bran composition and its stability to lipolysis, and in fact it has been reported that bran from parboiled rice is more stable than that from milled rice (Hermans, 1967). The following compositional data were recently reported for 1st and 2nd quality bran produced from raw and parboiled rice in Ceylon (Siriwardene, 1969), and are given in Table 3 below.

Table 3

Composition of Rice Bran from Ceylon

Analysis per cent	Bran from Raw Rice 1st Quality	Bran from Raw Rice 2nd Quality	Bran from Parboiled Rice 1st Quality	Bran from Parboiled Rice 2nd Quality
Dry Matter	89.1	88.9	89.9	90.1
Crude Protein	12.5	8.9	13.0	9.1
Oil	14.6	6.5	20.3	10.4
Crude Fibre	6.9	19.1	10.0	17.1
Ash	10.7	19.7	14.7	21.8
Nitrogen Free Extract	42.9	36.7	36.1	32.9

13. It will be noted that the oil content of bran from parboiled rice appears to be higher than that from raw rice.

14. Lastly, the new "X-M" method of simultaneously milling and solvent extracting rice so as to produce a stable edible bran ("Protex") should be mentioned (Lynn, 1969), but this process is to be dealt with in another paper to be presented.

Rice Bran as a Source of Edible Oil.

15. The oil content of rice bran is obviously very variable, but that produced in large efficient mills may be expected to contain 15-18 per cent of oil (Reddi et al, 1948). Refined rice oil produced from fresh or stabilised non-rancid bran is a useful edible oil roughly equivalent in properties to cottonseed or corn oil. However, the properties and uses of rice oil are to be dealt with in another paper to be presented.

16. One of the problems of producing rice oil in less developed countries is the scattered location and small size of most of the rice mills, which makes it difficult to collect suitably large quantities of fresh or stabilised bran for the production of oil on an economic scale. It is only when supplies are available from large mills that oil production is possible. These difficulties are reflected by the very low production of rice oil in most rice producing countries at present. Efforts are presently being made in Thailand to develop small scale steaming plants based on the autoclave principle, for stabilising bran from mills producing as little as 4 tons of bran per day (Hermans et al, 1970, Hermans, 1970). The greater stability of bran from parboiled rice has already been mentioned above.

17. Japan is by far the largest producer of rice oil with a current annual production of 90,000 tons of unrefined oil. This is produced from about one half the annual production of around one million tons of bran (Mitsubishi Shoji Kaisha Ltd., 1970). India and Burma are each estimated to produce about 20,000 tons of rice oil per annum, while Taiwan, South Korea, Thailand and the U.S.A. have estimated annual productions of 3,000, 6,000, 5,000, and 5,000 tons respectively (Anon, 1970 b). Total world production of rice oil is probably only slightly in excess of 150,000 tons per annum, excluding possible production in mainland China. This is, of course, well below potential production based on the total amount of bran produced, which in India alone may be not much less than a million tons (assuming the oil content of the likely production of 6 million tons of bran to be 15-18 per cent).

18. The method preferred for producing oil from rice bran is that of solvent extraction. It has been reported that some 20 years ago most oil was produced in Japan by hydraulic pressing, which only removed some 50 per cent of the oil (Reddi et al, 1948), but this has now been superseded by modern solvent extraction plants (Anon, 1970 b). The expeller process is less suitable due to the low oil content and bulk fibrous nature of rice bran. The solvent generally used is hexane. The solvent extraction of rice bran was extensively studied in the U.S.A. some 20 years ago (e.g. Reddi et al, 1948 and Graci et al, 1953), and various difficulties associated with the physical nature of rice bran were overcome to give a process suitable for routine commercial operation.

19. Solvent extraction does not lend itself to very small capacity working and the minimum size of plant which could be operated commercially would have a capacity of around 25 tons of bran per 24 hours. Assuming a 300 day per annum operation, this would entail a supply of about 7,500 tons of bran per annum i.e. the output from mills processing 75,000 tons of paddy. The annual production of crude oil from such a plant might be in the region of 1,000 tons per annum.

20. On the basis of current prices of edible oils with similar properties, the current value of rice oil might be in the region of US $ 380 per ton, while the value of rice bran might be only one tenth of this e.g. the quotation for rice bran in the U.S.A. during late 1970 was only $ 36-45 per ton. On this basis the sale of defatted rice bran and oil might be expected to yield around twice the revenue, which would be obtained by the sale of unprocessed bran, making it economically advantageous to increase rice oil production in the less developed countries of S.E. Asia and the Far East. However, it will be essential that adequate quantities of fresh or stabilised bran are locally available so as to provide sufficient raw material to sustain an economic scale of operation. It is unlikely that this situation will arise except in the context of large modern efficient rice mills, and the expansion of rice oil production will be dependant on progress towards the modernisation of rice milling in the less developed countries.

Rice Bran as Animal Feed.

21. Currently, rice bran is used almost entirely as an animal feed. It has already been mentioned that world production of rice oil is at present only around 150,000 tons per annum, meaning that only about one million tons of rice bran is defatted, and that all but 3-4 per cent of bran produced is fed to animals without further processing.

22. Figures given in standard reference works for the proximate composition and feeding value of commercially available rice by-products and other feed concentrates produced in S.E. Asia, are given in Table 4. It will be seen that rice bran and polish contain about 12-14 per cent of crude protein, which makes them rather superior in this respect to common feed cereals, but inferior to oil seed residues. The crude fibre content of rice bran is like wheat and maize bran rather high, but that of polish is much lower. Energy content as expressed by total digestible nutrients (calculated for ruminant animals) is quite high in the unextracted bran and polish but is obviously considerably reduced when the oil is removed. Defatted rice bran is comparable with wheat bran in energy content.

23. The high fibre content of bran makes it largely unsuitable for inclusion in unlimited proportions in rations for monogastric animals, and it must generally be mixed with a concentrate of lower fibre content e.g. cereals. Bran can be fed with greater freedom to ruminant animals, and can form a very high proportion of the concentrate component of the ration. The low fibre content of polish makes it very suitable for feeding as a high energy concentrate to monogastric animals, especially poultry.

Table 4

Composition and Feed Value of Rice Milling By-Products and Other Feed Materials, Per Cent.

Material	Moisture	Crude Protein (N x 6.25)	Oil	Crude Fibre	Ash	Nitrogen Free Extract	Digestible Crude Protein	Total Digestible Nutrients
Rice Bran	9.2	12.4	13.6	11.6	13.3	39.9	8.4	67.4
Extracted Rice Bran	9.1	14.3	3.1	12.0	13.6	47.9	9.7	55.3
Rice Meal	8.9	12.9	13.7	6.4	8.6	49.5	7.5	71.5
Rice Polish	10.2	12.8	13.4	2.7	9.9	51.0	9.7	81.5
Rice Husk	8.0	3.9	1.4	33.5	14.5	39.2	0.1	9.9
Wheat Bran	13.0	15.1	3.8	9.5	5.8	52.8	10.9	56.4
Maize Bran	11.8	8.4	4.2	11.7	1.9	62.0	5.5	70.9
Cottonseed Cake (undec)	12.0	20.3	4.8	21.8	5.8	35.3	15.6	49.1
Cottonseed Cake (dec)	10.0	41.1	8.0	7.8	6.7	26.4	35.3	72.1
Groundnut Cake (undec)	10.0	30.3	9.1	23.0	5.7	21.9	27.8	67.4
Groundnut Cake (dec)	10.0	45.4	6.0	6.5	5.7	26.4	40.5	75.6
Coconut Cake	10.0	21.2	7.3	11.4	5.9	44.2	16.6	76.4
Soya Cake	11.0	44.9	5.8	5.3	5.6	27.4	40.4	77.2

24. It has already been mentioned that there may be considerable mixing of rice by-products particularly in the smaller less efficient mills. This is not very serious if a mixed by-product containing bran, polish and broken endosperm is produced: this material is commonly marketed as "Rice Feed" and is still a very valuable feed with a fibre content intermediate between that of bran and polish. However, admixture to even a small degree with husk will seriously impair feed value, and render it unsuitable for feeding to monogastric animals. It is likely that most bran produced in less developed countries is contaminated to some degree with husk and it is in fact quite common for it to be graded according to husk content (e.g. Limangco-Lopez et al, 1962 and Siridarwene, 1969 already noted above).

25. The percentages of nutritionally important minerals in rice and its by-products are given in Table 5. It will be seen that rice is like most other cereals poor in calcium and iron, and rich in phosphorus. Most of the minerals of husked (brown) rice are concentrated in the pericarp and aleurone layers and the germ, and bran and polish are, therefore, comparitively rich in these. It has been reported that about 90 per cent of phosphorus in bran is present as phytin, and is, therefore, largely nutritionally unavailable (McCall et al, 1953).

26. As the B group vitamins of rice are like the minerals concentrated in the germ and pericarp and aleurone layers, bran and polish are rich in all of those which are nutritionally important with the exception of cyanocobalamin (B12). This makes them important sources of B vitamins for monogastric animals. Typical values for the vitamin B content of rice and its by-products are given in Table 6.

27. Rice protein is like other cereal proteins deficient in lysine, and this is in fact the limiting amino acid. Figures for the essential amino acid composition of rice and its by-products are given in Table 7, and it will be noted that the protein of bran and polish are markedly richer in lysine than that of milled rice. This is due to differences in proportions of the four main proteins of rice viz. water soluble albumin, salt soluble globulin, alcohol soluble prolamin and alkali soluble glutelin in the proteins of endosperm, bran and polish. It has been shown that the mean percentages of the four component proteins in samples of rice grown at the International Rice Research Institute, Philippines, were as follows (Cagampang et al, 1966) :-

	Albumin	Globulin	Prolamin	Glutelin
Milled rice	5	9	3	83
Bran	37	36	5	22
Polish	30	14	5	51

28. It will be seen that bran and polish are much richer in albumin and globulin than milled rice, due presumably to their greater presence in the germ and pericarp and aleurone layers of the rice grain. Only milled rice and polish have most of their protein as glutelin. As albumin contains more lysine than glutelin, it is

Table 5

Mineral Content of Rice and its By-Products, Per Cent.

Element	Brown Rice[1]	Milled Rice[1]	Bran[2]	Polish[2]	Protex Bran[3]
Calcium	0.08	0.01	0.06	0.04	
Phosphorus	0.29	0.10	1.82	1.42	1.50
Potassium	0.34	0.08	1.74	1.17	1.49
Magnesium	0.12	0.03	0.95	0.65	0.22
Iron	0.002	0.001	0.02	-	0.02
Manganese	-	0.001	0.004	-	-
Copper	0.0004	0.0002	0.001	-	-

1. F.A.O. (1948) 2. Panda and Gupta (1965) 3. Lynn (1969)

Table 6

B Group Vitamin Content of Rice and its By-Products, Micro g per g

Vitamin	Brown Rice[1]	Milled Rice[1]	Bran[2]	Polish[2]	Protex Bran[3]
Thiamine	3.0-5.0	0.6-1.0	24.0	22.0	10.6
Riboflavin	.0.8-1.0	0.28	2.0	2.2	5.7
Nicotinic Acid	55	15-20	336	330	308
Pantothenic Acid	17	6.4	27.7	33.3	-
Pyridoxine	10.3	5.5	25.0	20.0	19.2
Choline	-	880	1700	1021	-
Biotin	-	-	0.60	0.57	-
Inositol	-	-	4627	4536	-
p-Aminobenzoic Acid	-	-	0.75	0.73	-

1. F.A.O. (1948) 2. Kik (1956) 3. Lynn (1969)

Table 7

Essential Amino Acid Content of Rice Protein, g per 16g N

Amino Acid	Milled Rice[1]	Bran[1]	Polish[1]	Protex Bran[2]
Iso-leucine	4.63	3.94	3.80	3.60
Leucine	8.04	6.91	6.58	7.60
Lysine	3.51	4.81	4.66	4.11
Methionine	2.88	2.32	2.78	1.95
Cystine	2.52	2.32	2.57	
Phenylalanine	5.20	4.47	4.18	4.53
Tyrosine	4.86	3.13	3.39	3.18
Threonine	3.53	3.78	3.52	3.84
Valine	6.45	6.00	5.57	6.00
Tryptophane	1.34[3]	1.92[4]	1.42[5]	1.30

1. Houston et al (1969) 2. Lynn (1969) 3. F.A.O. (1970) 4. Kik (1956)

5. Lain and Rodriges (1965)

Table 8

Nutritive Value of Rice Protein, Per Cent

Determination	Brown Rice[1]	Milled Rice[1]	Germ[1]	Bran	Protex Bran[2]
Biological Value	72.7	64.0	78.1	-	-
Digestibility	96.5	97.9	86.9	-	-
Net Protein Utilisation (NPU)	-	57.2	67.9[3]	-	-
Protein Efficiency Ratio (PER)	-	2.18	-	1.6-1.9	1.7-1.9

1. F.A.O. (1970) 2. Kik (1956 and 1967) 3. Lynn (1969)

inevitable that the protein of bran and polish should be richer in lysine than that of milled rice (Houston et al, 1969).

29. This higher lysine content, which is some 37 per cent in excess of that of milled rice protein, gives bran and polish a considerable nutritional advantage over milled rice. This would be expected to be reflected in figures for the biological assessment of protein quality, but unfortunately there appears to be little reliable published data on this, and such that is available (see Table 8) does not really provide confirmation for this.

30. Before going on to discuss the experience gained in using rice bran and polish for animal feeding, it is necessary to mention once more the difficulties which may occur due to lipolysis. Unstabilised bran which has become rancid, may be unpalatable to animals, and it is, therefore, highly desirable to stabilise it by steaming. Solvent extraction will largely remove flavour problems but will reduce the energy value of the bran. The possibility of contamination with husk especially for material emanating from smaller mills should also be mentioned again, as the experimental results obtained (especially with monogastric animals) and the recommendations based on them, assume that the bran is uncontaminated with husk.

31. Rice bran and polish have been found to be very suitable for incorporation in pig rations, and there are many references in the literature to their use in this way especially in the U.S.A. However, it has been reported if fed as too large a proportion of the ration, serious scouring in pigs of less than 80 pounds weight could be caused, and that carcase fat may become too soft (Morrison, 1956). More recently, experiments were conducted to formulate revised recommendations for the use of rice bran in pig rations in the U.S.A. It was concluded that pigs weighing above 50 pounds could be fed a ration containing 20 per cent of rice bran, the other constituents of the ration being largely maize, soya meal and a vitamin/mineral mix. Rice bran could replace all the maize in rations for pregnant sows, constituting about 80 per cent of the total ration. Rice bran was not recommended for incorporation in rations for pigs of less than 50 pounds in weight (Thrasher et al, 1967). Satisfactory performance with regard to weight gain and carcase quality has been obtained for growing and fattening pigs fed on rations consisting largely of rice bran with either fish meal or soya meal in the Philippines (Bistoyong et al and Balderama et al, 1968 respectively).

32. Due to its low fibre content rice polish is particularly suitable for feeding to poultry, which have a low tolerance for high fibre rations. Its role in the ration is that of an energy provider replacing part of the cereals normally included for this purpose. The high requirement of poultry for B group vitamins makes bran and polish, which are particularly rich in most of these (see Table 6), very suitable for poultry rations. It has been shown in India that up to 40-45 per cent of cereals in poultry rations can be replaced by rice polish, and that it can be incorporated to the extent of 30 per cent of the total ration for laying birds (Panda and Gupta, 1965). Workers in the U.S.A. have shown that chicks fed

on a ration containing 10-20 per cent of polish gave a satisfactory growth performance (Upp, 1933). Although bran has a higher fibre content it can still be used for poultry rations provided that it is not contaminated with husk. Mixed bran and polish has been used to constitute as much as 40 per cent of the total ration for poultry in India (McArdle and Panda, 1960 and 1961). The same authors considered that bran with a fibre content in excess of 15 per cent (due presumably to husk contamination) should not be used in poultry rations. The removal of oil from polish by solvent extraction obviously reduces energy content. Workers in India have also produced evidence to suggest that growth promoting factors are removed with the oil, and that de-oiled bran supplemented with fat did not produce the same response as un-extracted polish (Sidhu and Nagpal, 1964).

33. The high fibre content of rice bran makes it most suitable for feeding to ruminant rather than monogastric animals. This is especially so if it is contaminated to any degree with husk. In fact most of the world production of rice bran is fed to ruminant animals as a concentrate to supplement the main ration of herbage and other roughages. For example it has been reported that in some rice growing states of India, rice bran may be almost the only concentrate fed to ruminants (Panda and Gupte, 1965). Workers in the U.S.A. have shown rice bran to be very suitable for feeding to dairy cattle, and when forming not more than one third of the dairy concentrate it was approximately equal in feed value to wheat bran. It was also reported that too great a proportion of rice bran in dairy rations could result in the production of soft butter (Morrison, 1956). Rice bran is also suitable for feeding as a large proportion of beef and dairy concentrates. It has been reported that it has been used to form up to 60 per cent of the concentrate ration of dairy cows, and working bullocks and buffaloes in India (Panda and Gupte, 1965).

34. Summarising, it will be seen that rice bran and polish are very useful materials for incorporation into feedingstuffs. Polish is especially suitable for pigs and poultry due to its low fibre content, while bran is most suitable for sheep and cattle. However, if these materials are to be used to feed animals in accordance with modern scientific principles, it is essential that they be very carefully graded with regard to possible husk content, and that only the highest grade materials with low husk content to be used for pig and poultry feed. In conjunction with this efforts should be made to minimise husk content of all bran and polish so as to ensure the highest possible nutritive value.

35. If it is intended to use unextracted bran as animal feed it is important that the oil be stabilised by steaming immediately after production if it is not intended to feed it very quickly to animals. Solvent extracted or steamed material must be dried to a safe moisture content level (say 14 per cent for fat free and 11 per cent for unextracted material) before storage if moulding is to be avoided (Panda and Gupte, 1965).

36. Assuming that stable products uncontaminated with husk are available there is no reason why rice bran and polish should not be major raw materials for the

industrial production of compounded feeds in S.E. Asia and the Far East, together with other locally available vegetable products such as cereals other than rice and their by-products, cottonseed and groundnut expeller cake, soya meal and molasses.

Export Potential for Rice Bran as Animal Feed.

37. There is a large and increasing demand for imported animal feed materials in the developed countries of Western Europe and Japan. To satisfy this demand large quantities of oilseed cakes and meals and other materials are exported from the less developed countries of the Far East and South-East Asia. Exports of rice bran at present form only a minor part of this trade but nevertheless the quantities already exported are by no means insignificant. For example official trade statistics show that 61,400 tons of solvent extracted and 1,356 tons of unextracted rice bran valued at around 12 million rupees were exported from India during the period April 1965 - March 1966 (Anon, 1966). There is no reason why this trade should not be expanded considerably provided that material of the appropriate quality can be produced.

38. Feed compounders in developed countries may use a great variety of materials in producing their feeds. The criteria which they employ in selecting raw materials are primarily those of nutritive value in relation to the feed in which they are to be incorporated and price, but obviously other factors such as the presence of toxic factors, palatability and stability must be taken into account. Competition between manufacturers in countries with well developed compound feed industries is so intense nowadays that they must keep a very close watch on raw material costs, and it is the general practise to regularly work out least cost formulations to achieve set nutritional specifications with the assistance of computers. This has led to much greater flexibility of use of raw materials, and has provided the opportunity for many new sources to be exploited. Nowadays, manufacturers are willing to consider any material which is offered to them provided that it meets specified standards with regard to quality and that the price is right.

39. If the export trade in rice bran is to be expanded it will be necessary to ensure that only consignments of certain minimum quality standards are exported. The material will need to be substantially free from husk, and if unextracted, the oil should have been stabilised. It will probably be necessary to provide specifications at least for minimum crude protein content (say 12 per cent and 14 per cent for unextracted and extracted bran respectively), and maximum crude fibre (say 12-13 per cent). Specifications of this type will also be needed for polish and meal (mixed bran, polish and broken endosperm).

40. If specifications are agreed with importers it is absolutely vital that they are adhered to. It is very annoying to compound feed manufacturers, if they cannot rely on the quality of their raw materials, and annoyance may be reflected in falling demand and lower prices. It should be emphasised that it is not sufficient to rely

on compensation clauses in contracts to allow for lapses in specified standards. This will obviously cover the importer for monetary loss for individual consignments, but will not compensate him for any additional trouble caused in including it in his formulations.

41. It is difficult to state a value for rice bran on the world market in precise monetary terms, as feedingstuffs vary in price depending on supply and demand. However, defatted bran would be expected to command a price similar or rather less than that of wheat bran. Undefatted rice bran should command a higher price provided that it had been stabilised and was not rancid, as the total digestible nutrients are about one fifth higher than those of defatted bran.

Present and Potential Use of Rice Bran and Polish as Food.

42. There is little need to repeat the many statements which have been made in recent years drawing attention to the current deficiency of protein in the diets of many inhabitants of developing countries (e.g. Anon, 1968). It is rather ironical that in South East Asia and the Far East many materials which have high contents of protein of high nutritive value are at present used(either internally or exported)as animal feed. Rice bran and polish are among these, and in 1969-70 some 12.5 million tons of these materials containing about 1.5 million tons of protein may have been used in this way in countries of the region other than mainland China (see Table 1).

43. It has already been noted that due to the higher proportions of albumin and globulin proteins in the pericarp and aleurone layers of rice, the protein of bran and polish is richer in lysine than that of milled rice (see Table 7). As lysine is generally considered to be the amino acid most deficient (i.e. limiting) in rice and wheat based diets, the advantages of utilising bran and polish to improve the nutrition of poorer members of the communities of the S.E. Asia/Far East region are even more evident. The high content of many members of the vitamin B group, which are often deficient in diets based on milled rice (F.A.O., 1948), would also make the possibility of using bran and polish for dietary purposes very attractive (see Table 6).

44. The main difficulties of using rice bran as human food are those of possible rancidity and high fibre content. The problem with regard to rancidity is best solved by extraction of the oil before rancidity can occur, and this has already been dealt with in some detail above. Certainly it is extremely unlikely that rice bran could ever be seriously considered for use as a food unless it were solvent extracted. The X-M process previously mentioned in which rice is milled and solvent extracted simultaneously, would appear currently the best method of producing bran suitable for use as food. It has been reported, however, that flavour problems can occur due to the 1-3 per cent of residual lipids in extracted bran, and steam treatment is essential to stabilise these (Lynn, 1969).

45. Air classification or sieving of finely ground solvent extracted bran, have been tried as methods of producing a material of lower fibre content and higher protein content more suitable for food use (Houston and Ali Mohammed, 1966). The results of experiments conducted with regard to air classification are summarised in Table 9 below. It will be seen that about one quarter of the starting material could be recovered as fractions (1 and 2) markedly lower in fibre and richer in protein than the original, but it was concluded that the overall results were generally unsatisfactory. Sieving was considered to be a simpler and perhaps more promising approach, and the results of passing extracted rice bran through a succession of sieves of increasing fineness are given in Table 10 below. It will be seen that about 30 per cent of the bran passed the 100 mesh sieve, and that this very fine material was rather richer in protein and considerably lower in fibre than the starting material. It was concluded that a sieving operation to recover about one quarter of bran as an edible material, might be an economic proposition in rice mills, particularly in world regions where protein was deficient.

Table 9

Air Classification of Flour from Defatted California Pearl Rice Bran
(All values on dry weight basis)

		Composition			
Fraction of Material	Weight %	Protein %	Ash %	Fat %	Fibre %
Original	100.0	18.6	7.37	0.91	11.4
Fraction 1*	17.0	19.4	10.7	.90	6.6
" 2	6.8	16.2	11.3	.74	6.1
" 3	4.7	12.4	8.95	.70	8.4
" 4	3.8	12.1	8.11	.90	8.4
" 5	3.5	11.0	6.50	.60	8.4
" 6	4.7	9.4	4.95	.67	8.0
" 7	4.9	8.9	4.21	.55	8.8
Residue	52.2	6.8	4.33	.56	13.8

* Particle size increases with fraction number.

46. The difficulties with regard to high fibre content do not apply to polish and it has been used in very limited quantities for incorporation in infant foods in the U.S.A. (Houston and Ali Mohammed, 1966). If polish and bran (and germ) are not separated during processing obviously the final by-product will be lower in fibre than normal bran. This is the case with proton the product of the X-M process, which has a reported fibre content of 6-8 per cent compared with that of as much as 18 per cent for normal extracted bran. Proton has been shown to be suitable for incorporation in a number of baked products including bread and biscuits up to an

much as 15 per cent without adversely affecting appearance and palatability. Its incorporation in products based on wheat flour would be expected to have a beneficial effect on protein utilisation due to the lysine supplementary effect on wheat protein which is deficient in lysine. Protex also contributes B group vitamins. Protex has also been used in proportions of up to one third with rice flour for the production of extruded products, possibly suitable as breakfast foods or snack bases.

Table 10

Sieve Classification of Defatted California Pearl Rice Bran
(All values on dry weight basis)

Fraction of Material	Weight %	Composition: Protein %	Ash	Fat %	Fibre %
Original	100.0	10.6	7.37	0.91	11.4
On 20-mesh	14.3	6.4	5.71	.79	12.9
" 40-mesh	27.5	8.9	6.31	.78	12.0
" 60-mesh	14.0	14.8	9.13	.90	13.3
" 100-mesh	9.2	16.0	9.19	.87	12.7
Through 100-mesh	29.3	11.9	9.23	.64	5.2

47. Summarising, there would appear to be considerable potential for the greater use of stable defatted rice bran and polish as human food, provided that in the case of bran, fibre it is reduced to acceptable levels. As yet, however, they have not been used to other than a very minor extent and there have as yet been few projections as to how they would be presented to the malnourished populations of S.E. Asia and the Far East. The best idea so far developed is probably for their incorporation in baked products such as bread and biscuits, but it is suspected that this approach would make little impact among rice eating populations.

48. Another approach to utilising defatted rice bran as a protein food is to use it as a raw material for the production of rice protein concentrate. This has the advantage of eliminating fibre and possibly undesirable residual lipids. However, this approach also has the disadvantage that other nutrients such as digestible carbohydrates and B group vitamins will be lost. The extraction process may also adversely affect protein quality by loss of nutritionally available lysine due to reaction between its epsilon-amino group and the carbonyl groups of carbohydrates (the Maillard reaction or non-enzymatic browning).

49. Protein concentrate may be prepared from defatted rice bran by extraction with alkali followed by iso-electric precipitation of solubilised protein from the extract by acidification. This is the technique commonly employed for the production of protein concentrates from defatted oilseeds and other cereal by-products.

Unfortunately, extraction at fairly high pH's is necessary to achieve reasonable yields of protein concentrate and even then extraction is far from complete. It has been shown that extraction at pH 11 (the optimum) solubilised only about 50 per cent of the protein of defatted rice bran. Precipitation of the solubilised bran at pH 5.5 yielded an 85 per cent protein concentrate corresponding to a recovery of 37 per cent of the protein in the starting material i.e. the rice bran (Chen and Houston, 1970).

90. A more detailed process based on these principles has been described for the production of a protein concentrate from protex bran (Lynn, 1969). This process is summarised in a simplified form in Figure 1. A feature of this process is the removal of carbohydrate enzymically before alkaline extraction, to avoid possible loss in protein quality due to non-enzymatic browning. The precipitation of the solubilised protein at pH 5.0 is said to yield an off-white bland paste containing 70-75 per cent of protein (dry basis). This may be dried to a stable film, or pressed to form a cheese-like material. A number of difficulties with regard to operating this process were pointed out. In particular the heat gelatinisation of the starch before enzymic hydrolysis may cause off-flavours and diminish protein solubilisation. Also optimum pH for solubilisation is critical, and tends to vary between different varieties.

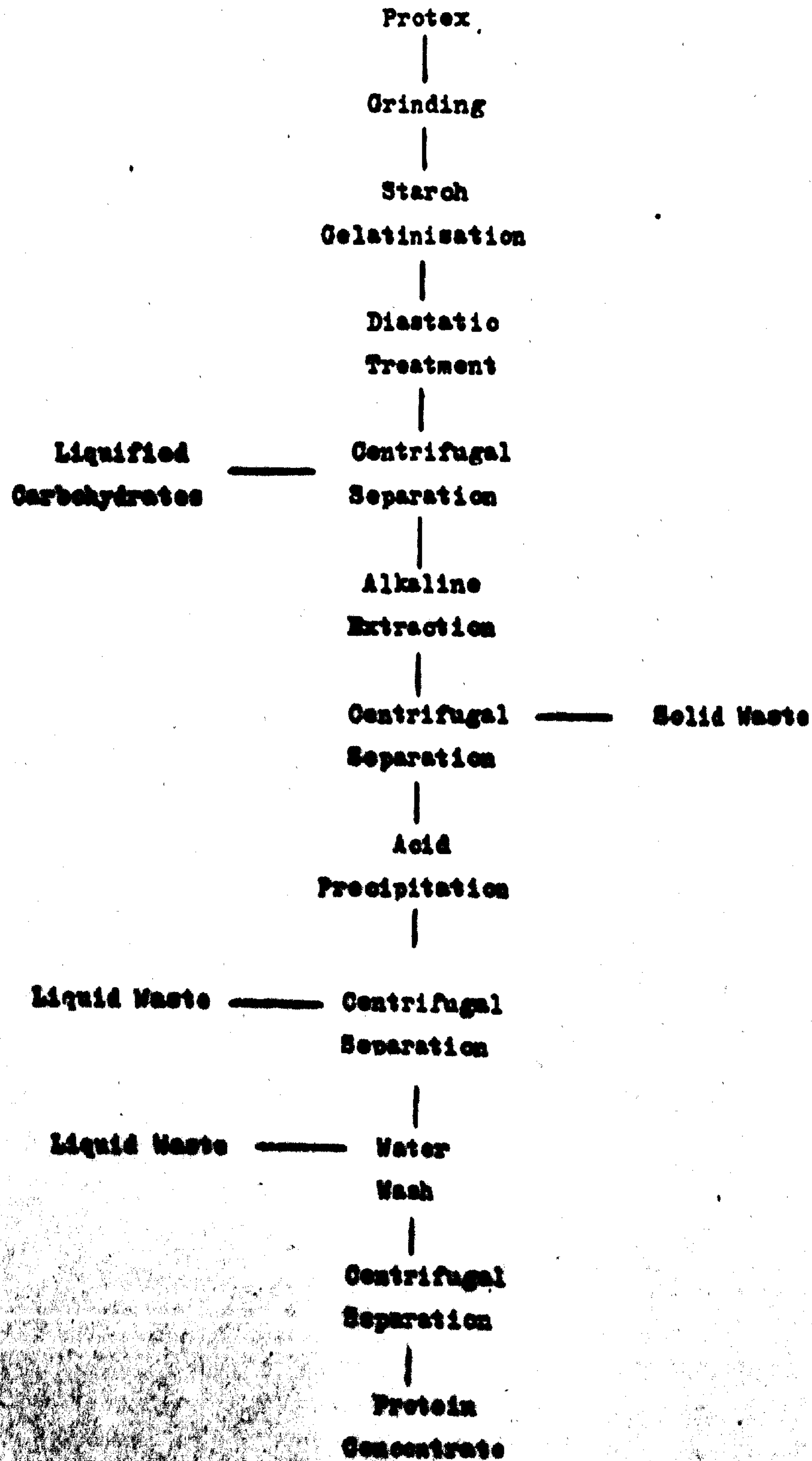
91. Rice protein concentrate can be used with rice flour to form extruded pasta type products with a protein content of 20-25 per cent (dry basis). It can also be used in combination with rice oil and suitable emulsifying agents to form an imitation milk containing 3.6 per cent protein, 4 per cent fat and 4.8 per cent carbohydrate. This imitation milk may be used to make various caramel confectionary products.

92. While the above possible uses for rice bran and rice protein concentrate have been demonstrated, commercial exploitation has up to now been minimal. The utilisation of rice bran and protein concentrate as food is fraught with the same difficulties which have faced all the new protein foods, which are those of marketing rather than food technology. This is especially true in developing countries where the potential customer who needs extra protein in his diet does not have the money to buy the processed foods which could be used as a vehicle for rice protein concentrate or bran. Those sections of the public which have money to spend on such foods may not really need them, and in any case may prefer to spend their money on something else. Initially, perhaps the most promising approach might be the marketing of an imitation milk of the type described above, on the lines of the highly successful "Vitasoy" of Hong Kong.

93. The possibilities of utilising new vegetable protein materials in developed countries e.g. for fortifying baked products or the production of textured meat analogues, are always overshadowed by the existence of unlimited supplies of soya flour, which is currently available at about 30 cents per Kg protein in the U.S.A.

Figure 1

Production of Protein Concentrate from "Protex"



Unless a market can be developed for foods in which specific desirable functional properties of rice bran can be exploited it is unlikely that edible rice bran or protein concentrate could be marketed to any extent.

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