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DRAFT STUDY ON THE DEFINITION OF THE MOST SUITABLE RICE BRAN STABILIZING TECHNOLOGY, ITS VERIFICATION AND THE SPECIFICATION OF ITS TECHNICAL PARAMETERS [1/]

by

Applied Scientific Research Corporation
of Thailand

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FOREWORD

Within its work programme for 1976, UNIDO initiated a global programme of research and development geared to the design and manufacture of a prototype, low cost rice bran stabilizer suitable for manufacture and use in developing countries where rice forms a main factor of food consumption and agroproduction output. The stabilizing equipment is to be characterized by the following basic criteria:

1. Suitable as an attachment to existing small and medium capacity rice mills;
2. An effective stabilization process is to be carried out by technically simple and unsophisticated equipment suitable for manufacture in developing countries;
3. No steam consumption;
4. No electricity consumption;
5. The use of rice mill by-products (husks) as fuel;
6. As far as possible automatic function not requiring (expert) attendance;
7. Easy maintenance - not involving mechanical parts - and limited repairs.

The project is planned to be implemented in co-operation with a number of selected international research and development institutions in the developed as well as developing countries. On this basis and in view of the Applied Scientific Research Corporation of Thailand (ASRCT)'s previous experience in rice bran stabilization technology, UNIDO offered ASRCT a Special Service Agreement covering the first phase of the project, i.e. verification of the most suitable rice bran stabilizing technology and definition of its technical parameters.

In order to lay the basis for the definition of an appropriate design of a small-capacity, low-cost rice bran stabilizing equipment for attachment to existing small rice mills, ASRCT agreed to undertake the following work:

1. Carry out literature surveys and prepare a literature survey report briefly outlining the work done by whom, when and where;

2. From the literature survey, extract those figures and data which are relevant for the design of a small capacity, low cost rice bran stabilizing prototype (heating temperature, heating time, heating means, stabilization efficiency, re-activation time, etc.);

3. Report on the work done by ASRCT in the field of rice bran stabilization by outlining:

   a) the objectives and aims of the research work carried out;

   b) the methods used;

   c) the results obtained;

   d) the conclusions drawn.

4. Based on the results obtained by ASRCT's own work and considering the results achieved by other institutes/organizations (literature review), elaborate one of more stabilization methods which the ASRCT considers effective as an appropriate basis for the design of a small capacity low cost rice bran stabilizing prototype. Describe the proposed method(s) in detail based on figures and data and elaborate (a) preliminary process flow diagram(s);

5. Carry out relevant laboratory and/or pilot plant tests in order to prove the technological, technical, biochemical and otherwise substantive feasibility and efficiency of the rice bran stabilization method(s)

the ASRCT wishes to recommend as the basis for the design of a small capacity, low cost rice bran stabilizing prototype to be attached to existing rice mills;

6. Specify the exact data of the recommended rice bran stabilization method(s), prepare (a) detailed and comprehensive process flow diagram(s) along with material and energy balance sheets(s) and elaborate (a) process description(s) explaining and outlining the proposed mode of operation.

In order to support the work outlined in items 1-6 above, UNIDO made available the services of Dr. S. Barber from the Instituto de Agroquimica y Technologia de Alimentos, Valencia, Spain as a rice bran processing expert to advise ASRCT staff for a period 3 weeks (September - October, 1976).

This report describes the findings as outlined above and specified in the UNIDO Purchase Order Contract No. 15-6-0027(76/23).

CHAPTER I
LITERATURE SURVEY

The work done on rice bran stabilization could be sectioned into the following categories:

A. Basic principles for rice bran stabilization.

B. Processes for the stabilization of rice bran.

C. Equipment for stabilizing rice bran.

D. Energy producing units.

A. BASIC PRINCIPLES FOR RICE BRAN STABILIZATION

Major causes of rice bran deterioration should be mentioned, they are: (a) enzymes, (b) microorganisms, and (c) insects.

Rice bran contains lipolytic enzymes lipases which, after being released during the milling process, promotes the hydrolysis of the bran oil into glycerol and free fatty acids. This reaction is due to the action of moisture in the presence of enzymes which acts as a catalyst.

The location of lipases in rice kernel and its characteristics has been reviewed by Desickachar (15). There is definite evidence that the lipases are present mostly in the layer just peripheral to the aleurone layers or in the testa or cross layer of the rice germs (47). When the bran is scoured and isolated from the grain during rice milling the enzyme and substrate are brought together and the lipolytic enzyme is triggered into activity.

Rice bran lipase is protein in nature with a M.W. of 41,000 (18,41). Optimum pH for activity is 7.4 to 7.6. Only small amounts of calcium although large concentration could inhibit the enzyme. Heavy metals (Cu^{++}, Zn^{++}), EDTA, CN^- and F^- as also alcohol and acetone inactivate the enzyme. Heating of the enzyme solution at 60°C for about 10 minutes has been found to inactivate the enzyme.

Of those enzymes responsible for lipid alteration, peroxidase was found to be the most resistant to heat treatments ... it has the capacity to recover activity, even after inactivation. Oxiditive deterioration caused by perioxidase is favorable at low moisture content levels.

Rice bran was found to be highly contaminated by microflora, with reported counts for bacteria and mold, respectively, 3,770,000 and 110,000 per gram (5). The microbe contaminants were found to be species of Endomycopsis, Aspergillus, Mucor, Penicillium, Fusarium and Bacillus (26). These microorganisms produce the lipases which increases the FFA content of rice bran (26), while also producing the dangerous mycotoxins.

Other contaminants were found to be insects which included the rice weevil Sitophilus oryzae L., granary weevil Sitophilus granarius L., and rice moth Corcyra cephalonica Staint.

As mentioned previously, heat is a suitable means in inactivating enzyme lipase. Additional advantages of heat treatment are that it can simultaneously kill microorganisms and insects.

The influence of variables involved in heat processing -- temperature, time, moisture and pH -- of the bran on the peroxidase activity was studied by Barber et.al.(7). It was found that the heat resistance of enzyme responsible for deterioration depends not only on the time and temperature of treatment but also on the moisture content of the bran. At moisture levels of 25-35% and 20%, after two minutes treatment, less than 2% and more than 20%, respectively of the initial peroxidase activity still persisted. At a lower moisture content of the bran (20%) a longer length of exposure to heat is needed to inactivate the enzyme. The initial enzyme activity is lower with lower pH. However, the velocity of enzyme inactivation seems to be similar in all cases.

Heat treatment also causes agglomeration of the bran into coarser sized particles preventing the problems caused by fine particles during solvent extraction of oil (15,24,49).

In order to determine the effects of heat on enzymes, most workers measured the FFA produced by the action of lipases on fat. The method proposed by San Clemente and Vadehra (40), with slight modification, were used in finding out the lipolytic activity of enzymes (43).

With regard to the inactivation of enzymes of rice bran, special attention was given to peroxidase due to its being the most resistant to hydrothermal treatments especially to its capacity, after inactivation, to recover activity. Thus, peroxidase activity could be used as an index of rice bran deterioration through the utilization of a Vetter, et.al. (44) modified analytical method.

Heat treatment not only inactivated enzyme lipases, but also, more or less, affected nutritive ingredients and toxic substances in rice bran. At least, the color of oil extracted from heat treated bran is changed to a darker shade (50). Heat treatment denatured proteins and proteins may reacts with reducing sugars, known as maillard reaction. It is well accepted that rice bran is rich in vitamin, especially thiamine -- even though, heat treatment in the IATA (Instituto de Agroquimica y Technologia Alimentos) Process to stabilize rice bran decreased thiamine content about 5% (5).

Natural toxicants reported in rice bran were trypsin inhibitor and hemagglutinin. Over 95% of the total activity in grain is located in the germ and all the rice germ is in the bran. The antitrypsin activity of 1.00 TUI/mg. of sample, dry basis, was found in commercial rice bran (6). Hemagglutinating activity in commercially degermed bran was found to be 160 HU/g (6). Stabilization of commercial rice bran, involving 3-4 minutes steaming and subsequent flash drying was proven to completely destroy hemagglutinating activity, and also trypsin inhibitor (8,6).

B. PROCESSES FOR THE STABILIZATION OF RICE BRAN

Most of the processes developed for the stabilization of rice bran involved dry or moist heat treatment. Use of chemicals, gamma irradiation, as well as storage under inert atmosphere have also been suggested although they have never been accepted as reliable or practical procedures.

Chemical treatments such as with 0.31% ethylene chlorohydrin, 0.03% sodium cyanide, 0.19% propylene glycol diproprionate, 0.03%, 1,3-dimethyl-4, 6-bis(chloromethyl)benzene, 5-20% sodium fluoride, 5-20% sodium bromide, 5-10% sodium chloride, 5-10% potassium iodide, 0.5-1.0% Topanol OF and Topanol OC were ineffective in preventing the development of FFA (3,27,34). Storage of rice bran under carbon dioxide, nitrogen gas, or vacuum were also ineffective in preventing deterioration (27).

Rice bran was also irradiated with gamma rays at the rate of 1,200,000 R. After 6 weeks storage the FFA content increased from 2 to 3% (16). This dose of gamma radiation seems to inhibit completely the activity of the lipolytic enzymes in the rice bran. The application of this method on an industrial scale depends not only on the economic potentialities of the process but also the problem in attaching the process at the mill site. Secondary effects were not reported.

In the new X-M Process for the extraction of oil from rice bran, the oil was extracted the moment the bran was released from the rice. Hence, the oil recovered was almost fully at a very low FFA. However, the solvent extracted rice bran still contains a small proportion of oil (0.5-2.5%) and can continue to degrade (28). Even here, the extracted bran will have to be heat treated for the destruction of the enzyme, as well as, for desolventisation.

Besides, the processes of stabilizing rice bran stated above, other treatments can be divided into two groups: dry and moist heat processing of rice bran.

1. Dry heat processing of rice bran

Possibilities of dry heat treatment have been extensively investigated. A paper published in 1933 deals with this subject in detail (48). In general, dry heat does not inactivate lipases totally. Many papers state that only partial inactivation is achieved (48,51). The temperature used inactivating lipases should be about 105°C (48).

The present status of knowledge regarding dry heat processed is tabulated in Table 1. The table, covering heating means, treatment condition, moisture content of bran after stabilization and during storage, keeping quality, as well as comments, is used as a direction for the dry heat treatment discussed below.

Means of heating as a basis for the description of processes can be classified under the following categories:

(a) Pan with stirrer;

(b) Oven or chamber;

(c) Jacketed drum;

(d) Revolving drum;

(e) Screw conveyor;

(f) Fluidized or moving bed;

(g) Oil expeller.

The bran heated at 110-120°C for 15-20 minutes in a pan, was tested for enzyme activity. It is apparent that the temperature and time used was sufficient to inactivate lipases (43). However, in outlying districts in the Philippines, the fresh bran was heated and stirred in a frying-pan over a direct low fire for an hour charred the bran (48). It is reported that the treated bran could be kept for only one week, in a tightly closed container.

Inactivating the bran in an oven or a chamber was reported in many papers (1,3,4,19,27,35,48,50). The heating temperature used ranged from 90° to 200°C and the time used ranged from 5 minutes to 6 hours. The low moisture content (2-5%) of stabilized bran was also applied as a required factor (27,50).

Jacketed drum or cylinder provided with steam was used as a selective process to stabilize rice bran (9,31). An effort was made to heat the bran thoroughly, hence, a steam rotary dryer was employed (29,30,34,48). Quite a wide range for heating temperature (80-150°C) and times (3 minutes to 3 hours) were used.

In addition to the steam, used to generate heat for the jacketed drum, oil burners and electricity were also employed to provide heat to the rotary drum (39,47). The temperature used ranged between 110° to 150°C with the time ranging between 3 to 10 minutes ... with the results shown in Table 1.

The steam jacketed screw conveyor was another alternative employed as a inactivator device for a small factory in Taiwan (14). Flue gas generated by burning agricultural wastes was also employed to heat bran being conveyed by a screw in a tube (33) ... with the rice bran temperature 80°C at discharge. The capacity of the unit was about 8-16 kg/hr. at 2 to 4 r.p.m. After 32 days storage the FFA content increased from 3.5 to 5.9 percent, for double pass treated rice bran.

It is believed that, if rice bran is uniformly exposed to the environment for an appropriate length of time, rice bran enzymes may be satisfactorily inactivated. Therefore, fluidized bed or moving bed was adopted. In such processes, air, produced either by air compressor or blowers was used as a medium for transferring heat. It seems to be a high temperature (105-200°C) and short time (1 second to 10 minutes) process which includes a laboratory scale stirred fluidized bed (32), combined phase fluidization (25), and pneumatic conveying dryer (36).

The possibility of using some form of frictional heat of an oil expeller for developing required temperature to inactivate the enzymes in raw bran has also been reported (16). It was found that effective control of lipases is possible only when the temperature attained by the bran at the discharge end is 110°C.

The efficiency of processing is measured by FFA development during storage, but neither the storage condition nor the size of bran sample were given. There is a lack of knowledge of secondary effects.

The data in Table 1 shows quite a wide range in the effects, and the optimum value for the time and temperature recommended differed dramatically (2,4,48). Some papers claim that FFA content will not increase after heat treatment, provided moisture content was kept at about 5 per cent (27,31,34). Most of the authors recommended that the stabilized bran must be stored in moisture-proof container to prevent the moisture rising higher than 3-5 per cent (14,48). Under this condition, oxidative deterioration of oil may take place, however, no reference to it is available.

2. Moist heat processing of rice bran

Moist heat has generally proved to be the most effective in inactivating lipases. Treating bran with live steam at atmospheric pressure for 3 minutes, the enzyme activity seems to be absolutely terminated (43).

When moist heat is used to inactivate lipases, the process is normally followed by drying and or cooling. Moist heat processing of rice bran results are tabulated in Table 2. The table covers the heating, drying and cooling conditions, moisture content of bran after stabilization and during storage, keeping quality, as well as comments ... and has been used for moist heat treatment method discussion below.

Means of moist heat treatment as a basis for the description of processes were classified into the following categories:

(a) Steam cooker and allied process;

(b) Rotating drum;

(c) Tempering and preconditioning units of oil expeller;

(d) Screw conveyor;

(e) Screw extrusion.

The most simple process for moist heat treatment of raw bran was done by steaming the bran in a steam cooker or autoclave (9,10,39,43,46). The steaming temperature and time varied between 100-125°C and 1 minute to 3 hours. Very few references were available on the drying and cooling conditions after inactivating (26,46). Tunnel exhausters in canning lines were also used as a steaming unit ... however, stabilization could not be achieved (10). Instead of direct injection of steam into the bran, some workers added water until the moisture of the bran had reached 17 to 40 per cent, and then dried it either in a grain or a rotary dryer (10,34)... however, the treated bran was not stabilized by this mean. The bran may not have been steamed thoroughly and the keeping quality, thus, differed extensively (43).

Rotating drum was used as an alternative in trials to steam the bran homogeneously (20,34). The bran was steamed at 100°C for 5 mins, then dried and cooled (20). This treated bran kept satisfactorily for 3 months.

There are several other methods employed in the treatment of parboiled rice or oil seeds, offering certain possibilities as stabilizers, e.g. tempering and preconditioning units of oil expeller and parboiling steam kettles (45). The treated temperature was between 95-97°C for 8 to 30 minutes. Moisture picked up during steaming was 2 to 3 per cent, but this was lost during overnight shade drying. It is reported that the treated bran remained stable for approximately 25 days (45).

A patented method of enzyme inactivation was proposed to take place in a 90-foot screw conveyor divided into sections to steam (100°C), dry (102-104°C), and cool the bran (13). A Japanese plant consisting of three successive screw conveyors (steamer, drier, and cooler) needs the removal of the final moisture content of bran to 3 per cent to assure good keeping quality (50,51).

Instituto de Agroquimica y Technologia de Alimentes (IATA) in Spain has developed the IATA process shown to be especially suitable to industrial requirements (7,17). The process begins by direct heating and wetting the bran with steam in a U-shaped through mixer. The bran then runs through a steam jacketed screw conveyor where treatment is completed. The inactivited bran is unloaded into a flash dryer to get a dry and cool powdered product. The complete process takes about 4 minutes. Storage tests have proved the irrevesibility of the enzymatic inactivation illustrating what appears to be the real stabilization of fresh rice bran with properties achieved being suitable for commercial purposes (7,17) ... and the stabilized bran claims 6-months safe storage.

The principle of screw extrusion was used in the stabilizing method. Adequate moistened raw material was pressed into a specially designed indirectly heated chamber and forced through a die, followed by drying & cooling (7,17). The stabilized bran could be kept for 6 months. However, this process has not been used or scaled-up at present. A similar process was employed by Anderson Company, known as the Expandolex Process (2,49). The expander was a high speed, high pressure unit and the treated rice bran was dried to between 7 to 10 percent moisture levels. It was reported that the FFA content remained stable for 84 days.

C. EQUIPMENT FOR STABILIZING RICE BRAN

Most of the available papers deal with the processes carried out at the laboratory scale. Only a few of which are listed and described briefly below were used in pilot plant units.

1. Dry heat processing equipment

(a) Electrically heated roaster (47). The stabilizer is an electrically jacketed revolving drum provided with a tightly fitted lid. After charging the bran into the toaster, the temperature is maintained at 110-115°C for 5 minutes. The moisture content of the bran is reduced to 8 per cent. The stabilized bran is then allowed to cool. The capacity of the toaster is about 20-25 kg. bran per batch.

(b) Steam jacketed screw conveyor (14). A small factory at the capacity of 15 MT/day was biult up in Taiwan. The stabilizer composed of steam jacketed screw conveyor in whish bran is heated and dried to inhibit the enzymatic action and stop oil decomposition. The treated bran is then air cooled before packing in moisture proof container.

(c) Steam jacketed inactivator (29). The system requires an inactivator and a cooler. The inactivator is a steam or hot water jacketed drum provided with the helix agitator. The bran is maintained in the inactivator at 105°/110°C for a period of time and then discharged to the conveyor belt cooler. The capacity of the equipment is about 1 ton/batch. It is reported that the equipment is suitable for mills with capacity up to 5 tons/hr. of paddy.

2. Moist heat processing equipment

(a) Japanese plant (50,51). It consists of three successive screw conveyors to steam, dry and cool the bran. Raw rice bran was picked up by a bucket elevator through the steam cooker, steamed to 95°C for 3 minutes, and then flows down to two continuous dryers. The moisture content of the treated bran is reduced to 3-4 per cent. The dried bran is then air cooled.

(b) Micro-stabilizer (20). The plant has one rotating drum steamer, one dryer and one cooler. The bran is steamed at 100°C for 5 minutes, dried at 50°C for 40 minutes with hot air and is atmospheric cooled to 25°C for 15 minutes. The moisture content of stabilized bran is about 10 per cent. It is reported that the bran is capable of 3 months safe storage.

(c) U.S.A. patented plant (13). Is a 90-foot screw conveyor divided into sections to steam (20 foot), to dry (60 foot) and to cool (10 foot) the bran, respectively. The bran is expelled from the hopper and emptied into a screw conveyor where it is steamed at 100-121°C for 1.5 minutes, then dried at 102-104°C for 3 minutes and cooled for 0.75 minute.

(d) Expandolex (2,49). The expander is a high speed, high pressure unit. The bran is conveyed through the barrel by a continuous worm shaft toward the discharge plate, water and steam (121-138°C) are added raising the moisture level and completely blending and mixing the material. As the sterilized bran is extruded from the expander through the die plate, the sudden decrease in pressure causes the liquid water to vaporise.

After expansion, the rope-like or crumble products is usually dried to 8-10 per cent moisture levels and, also, to harden the particles. It is claimed that, there was no change in FFA content after storage for 84 days. However, the unit requires large capacities (100-300 ton bran/day), needs high investment, and high power consumption.

(e) IATA stabilizer (7-17). The unit comprises an inactivator, a dryer and a cooler. The inactivator consists essentially of a U-shaped trough mixer (primary stabilizer) with the bottom perforated by a series of small holes through which steam is injected, and a thermally insulated screw conveyor (secondary stabilizer) which acts as an "extra-holding" body.

As fresh bran enters the primary stabilizer, steam condensation increases its moisture about 5 percentage units and heats it to the equilibrium operation temperature. In these conditions enzyme inactivation including peroxidase is rapidly effected. Finally, resulting treated bran is flash dried and cooled to room temperature. Total processing time, including drying and cooling, is about 4-5 minutes.

IATA process has been shown to be especially suited to industrial requirements (5). The unit is continuous, easy and simple to operate, practically only a watchman is required in operating the equipment. It is made from low cost material. The equipment is compact and does not require any special work to install. Its production rate can be varied to suit requirements. At present, plants have been constructed to meet requirement of two different production rates: (a) pilot plant scale: about 100 (50-200) kg. bran/hr., and (b) commercial scale: about 450(100-500) kg. bran/hr.

D. ENERGY PRODUCING UNITS

All stabilizers developed require either hot air and/or steam production, therefore, a boiler is used as a steam generator. Few references mention the source of energy used in rice bran stabilization (5,38). One adopted an oil (petroleum) burner as a heat source for rotary drum (38), and another used gas-oil, petroleum, or fuel-oil as steam generator in stabilizing bran (5). Only one group used flue gases, generated by burning agricultural wastes or any solid fuel to heat the tube in which bran was stabilized (34).

There is a need for simple, low-cost, locally manufactured stabilizer utilizing rice husk as the fuel for steam and hot air for mill use (20). However, solely, stabilized bran using rice husk is under studies at TATA, Spain (5).

Table 1. Dry heat processing of rice bran

	Heating means	Treatment condition			Moisture content, %		Keeping quality			Comments	Reported by	Reference
		Temp. °C	Time pressure	Feed rate (Capacity)	After stab.	During storage	Container	Time storage	FFA, % etc. specified			
Pan with stirrer	Low speed stirrer thermostically controlled oil bath	100 110 120	20 min. 20 " 15 "						Enz. Activity 0.14 0.00 0.14	Lipolytic activity of fresh bran = 1.04	Srimani, et. al. 1974 India	43
	Frying pan	low fire	1 hr.				glass jar	1 wk.		-local used, district. -darker bran.	West & Cruz, 1933 Philippines	48
Oven or chamber	Heated chamber	95						85 d.	5.3 → 17.6		Akiya, 1967 Japan	1
	Oven (6-8 mm. thickness)	120 160 200	25 min. 15 " 5 "					32 d. 32 d. 32 d.	3.1 → 8.6 3.1 → 6.9 3.1 → 7.4	at 200°C, triglycerides glycerals + F.A.	Arnott & Lim, 1966 Malaysia	3
	Oven	110	5 min.					13 wk.	acid value 105 → 165	slow down but not completely prevent it	Aslam & Ali, 1963 Pakistan	4
	Infra red heating Indirect heating	120 105	15 min. 15 "							definit increase in FFA is noted	Gomez Fabra & Primo Yufera, 1953 Spain	19

Table 1. (Continue)

	Heating means	Treatment condition: Temp. °C	Treatment condition: Time pressure	Treatment condition: Feed rate (capacity)	Moisture content, %: After stab.	Moisture content, %: During storage	Keeping quality: Container	Keeping quality: Time storage	Keeping quality: FFA, % etc. specified	Comments	Reported by	Reference
Oven or chamber	Forced draft oven	85 70 100 100 110	3 hr. 3 " 2 " 3 " 3 "		3.54 4.90 2.54 2.37 2.06	3.50 4.16 2.44 2.26 1.86	Mason jar	18 wk. 25 " 18 " 18 " 18 "	5 → 6 5 → 7 4 → 5 4 → 5 4 → 4	initial moisture content 12.9 % storage at 25°C	Loeb, et.al., 1949 U.S.A.	27
	Oven	105 reheat	2 hr.				glass bottle	10 d. 40 d.	3.0 → 4.1 4.1 → 7.6	incomplete inactivation of lipase.	Rao & Murthy, 1955 India	35
	Electric drying oven with stirrer	98-100	6 hr.				cheese cloth sacks in wire box	7 d.	6.8 → 12.7	remove all moisture destroy enzymes.	West & Cruz, 1933 Philippines	48
	Oven	100 50-60	6 hr.		3	5.4	cellephane	1 mo.	acid value 5.4 → 5.5	moisture proof container lipases are temporarity inactivated	Yokochi, 1972 Japan	50

Table 1. (Continue)

Heating means		Treatment condition: Temp. °C	Time pressure	Feed rate (capacity)	Moisture content, %: After stab.	During storage	Keeping quality: Container	Time storage	FFA, % etc. specified	Comments	Reported by	Reference
Jacketed drum	Steam jacketed drum	110-115	10-33 min.					5 wk. 5 "	15.4 → 47.2 19.6 → 35.0		Bhumiratara, 1969 Thailand	9
	Steam jacketed drum	110	90-120 min.		4		Moisture proof bag	3-4 mo.		Pest infestation was controlled	Pe, 1971 Burma	31
Revolving drum	Steam jacketed revolving drum	105-110		1 ton/batch						Suitable for mills up to 40 tons paddy in 2 hours.	de Oliveira, 1976 Spain	29
	Rotary Dryer	(130)	1-1½ hr. 25 psig				Polythene bag in gunny bag	105 d.	→ 20		Pe, year not available Burma	30
	Steam heated rotary dryer (pilot plant)	80			2.3	4.3		28 d.	2.8 → 13.0		Rao, et.al., 1967 India	34

Table 1. (Continue)

	Heating means	Treatment condition: Temp. °C	Treatment condition: Time pressure	Treatment condition: Feed rate (capacity)	Moisture content, %: After stab.	Moisture content, %: During storage	Keeping quality: Container	Keeping quality: Time storage	Keeping quality: FFA, % etc. specified	Comments	Reported by	Reference
Revolving drum	Rotary drum	110,120, 130,140, 150	3,5,10 min.	100-500 g/min.	4.20 2.85 0.99 1.30 2.85	4.28 4.20 3.10 3.10 4.01	Polythene, cloth, gunny bag	4 wk. 33°C	9.2 → 15.2 9.1 → 15.2 9.2 — 14.7 9.5 → 15.2 9.2 — 14.4	Extraction yield of treated bran of 3 d. storage was 16.7 % compaing with 10.[illegible]% of raw bran	Rhee, et.al., 1974 Korea	38
Revolving drum	Electrically jacketed revolving drum	110-115	5 min.	20-25kg/ batch	6-8		Cloth bag	at 37°C 4½ mo. 30 d.	4 → 10 4 → 5	- Temp. effective 100-110°C - Stab. cost U.S.$ 5/ tonne	Viraktamath & Desikachar, 1971 India	46
Revolving drum	Jacketed drum-shaped apparatus with iron peddle stirrer	125					Moisture proof	Considerable length			West & Cruz, 1933 Philippines	48
Screw conveyor	Steam jacketed screw conveyor			15 MT/ day			Kraft paper bag lining with polythene	Several day			Chu, 1963 Taiwan	14

Table 1. (Continue)

	Heating means	Treatment condition: Temp. °C	Treatment condition: Time air	Treatment condition: Feed rate (capa- city)	Moisture content, %: After stab.	Moisture content, %: During storage	Keeping quality: Con- tainer	Keeping quality: Time sto- rage	Keeping quality: FFA, % etc. specified	Comments	Reported by	Refe- rence
Screw conveyor	Screw conveyor, flue gas heated tube	80 at dis- charged end		8-16 kg/hr. at 2-4 r.p.m.	2.6	2.8		32 d.	3.5 → 5.9	- double pass - stab. cost U.S.$ 6.25/ tonne	Reddy, et.al. 1974 India	33
Fluidized or moving bed	Combined phase fluidization	110	1 sec. 4 m^3/ sec.	30 kg/hr.				4 wk.	O.K.	- steam jac- keted - problems in separating sand	Khemchand & Gupta, 1975 India	25
	Fluidized bed	105	10 min. 3.65 m^3/ hr.	250 g/ batch			Poly- thene bag	23 d.	3.88 → 4.39	- batch, dis- tributors, stirrer, air compressor. - temp. of treatment is important.	Ramkrishnia, et.al., 1973 India	32
		120	5 min. 3.85 m^3/ hr.					18 d.	3.10 → 3.85			
	Pilot plant pneumatic con- veying dryer	200 (air inlet)	[illegible] m^3/ hr.	30-50 kg/hr.	3			23 d.	2.2 → 3.5	M.C. 4% destroy enzyme activity	Rao, et.al., 1965 India	36
Oil expeller	Oil expeller	110 (dis- charge end)		5 kg/hr.			Cloth bag	25 d. at 37°C	6.0 → 8.0	Continuous	Viraktamath & Desikachar, 1971 India	46

Table 2. Moist heat processing of rice bran

	Heating/steaming						Drying			Cooling	Moisture content, %		Keeping quality					
	Unit	H_2O	Steam pressure	Temp.	Time	Feed rate (capacity)	Unit	Temp.	Time	Unit	After stab.	During storage	Container	Time storage	FFA, % etc. specified	Comments	Reported by	Reference
Steam cooker and allied process	Atmospheric cooker		8 kg/cm^2		30 min.		Dryer							7 wk.	5 → 11		Bhumiratana, 1969 Thailand	9
	Tunnel exhauster		45–55 kg/cm^2		30 min.									20 wk.	3.8 → 21.6	Insect infestation	Bhumiratana, 1970 Thailand	10
	Autoclave (small samples)		15 lbs	121 °C	3 hr.			85 °C 60 °C	5 hr. 1 "					20 d.	R.H.* 68% 2.3 → 2.4 R.H. 80.3% 2.9 → 2.8 R.H. 100% 2.6 → 2.8		Loeb & Mayne, 1952 U.S.A.	26
	Lab. scale (small samples)			212 °F	1–4 min.									4 wk.	3 — 5	Definite increase in FFA	Roberts, et.al., 1949 U.S.A.	39
	Lab. scale (small samples)		atm.		1 min. 2 " 3 "						16				enz. activity 0.714 0.357 0	- Initial lipolytic activity 1.24 - Subsequent drying should be done	Srimani, et.al., 1974 India	43

* Relative humidity

Table 2. (Continue)

	Heating/steaming						Drying			Cooling	Moisture content, %		Keeping quality			Comments	Reported by	Reference
	Unit	H_2O	Steam pressure	Temp.	Time	Feed rate (capacity)	Unit	Temp.	Time	Unit	After stab.	During storage	Container	Time storage	FFA, %, etc. specified			
Steam cooker and allied process	Steam cooker (in layers)				30 min. 15 "		Cabinet drier				< 10			80 d. 37°C	3 --- [illegible] 3 --- [illegible]		Viraktamath & Desikachar, 1971 India	46
	Grain dryer	to 25%	No				Grain dryer	110-115°C	60 min 70 " 80 " 90 "		4.5 7.3 6.6 4.7			16 wk 24 " 24 " 24 "	8.4 → 21.6 6.1 → 19.7 5.6 → 12.4 6.2 → 1[illegible].5		Bhumiratana, 1970 Thailand	10
		to 40%	No				Grain dryer	110-115°C	60 " 70 " 80 " 90 "		14.3 11.1 6.1 5.9			24 " 24 " 24 " 24 "	6.1 → [illegible] 6.2 → [illegible] 6.4 → [illegible].7 5.9 → [illegible].4			
	Rotary dryer	to 17%	No				Rotary dryer				3.0	5.9	Gunny bag	11 "	[illegible] → 1[illegible].0		Rao, et.al. 1967 India	34
Rotating drum	Rotating drum			100°C	5 min.	0.5 tonne/hr.	Hot air	50°C	40 min	25°C 15 min				3 mo	[illegible]	Stab. cost £2.5/tonne	Hawkey, 1975 U.K.	20
	Drum with stirrer	1.2% increase	atm.		5 min.		Fluidized bed ½ ton/day	125-266°F			2.1-3.1			3 mo	+0.8	5 HP motor dryer	Bose & Srimani, 1974 Srimani, 1972 India	12 42

Table 3. (Continue)

	Heating/steaming						Drying			Cooling	Moisture content, %		Keeping quality					
	Unit	H_2O	Steam pressure	Temp.	Time	Feed rate (capacity)	Unit	Temp.	Time	Unit	After stab.	During storage	Container	Time storage	FFA, % etc. specified	Comments	Reported by	Reference
Tempering & preconditioning unit	Tempering unit		atm.	95-97°C	15 min.	1 ton/hr.	Shade dried		Overnight		8.2	6.0	Jute bag	10 d. 40 "	7.4 → 8.4 7.4 → 20.2		Viraktamath 1974 India	45
	Preconditioning unit of large expeller		atm.	95-97°C	15 min.	1 ton/hr.	Shade dried		Overnight		8.7	5.8	Jute bag	10 d. 40 "	9.8 → 10.9 9.8 → 20.1			
	Preconditioning unit of small expeller		atm.	95-97°C	8 min.	0.25 ton/hr.	Shade dried		Overnight		8.9	5.2	Jute bag	10 d. 40 "	9.7 → 9.8 9.7 → 15.0			
	Steaming tanks			95°C	15 min.	0.25 ton/batch	Shade dried		Overnight		8.5	6.5	Jute bag	10 d. 40 "	9.6 → 10.6 9.6 → 33.4	Protection against insect infestation		
					20 "						8.8	6.8		10 " 40 "	6.3 → 7.0 6.3 → 31.1			
					30 "						9.5	6.4		10 " 40 "	6.8 → 7.1 6.8 → 28.8			
Screw conveyor	90-foot screw conveyor			212-250°F	1.5 min. (20 ft.)		Conveyor	216-220°F	3 min (60 ft.)	Conveyor 0.75 min. (10 ft.)				4 wk	4 → 6	Steaming increased M.C. 3-5%	Burns & Cassidy, 1974 U.S.A.	13

Table 3. (Continue)

	Heating/steaming						Drying			Cooling	Moisture content, %		Keeping quality			Comments	Reported by	Reference
	Unit	H_2O	Steam pressure	Temp.	Time	Feed rate (capacity)	Unit	Temp.	Time	Unit	After stab.	During storage	Container	Time storage	FFA, % etc. specified			
Screw conveyor	Screw conveyor			95°C			Steam jacketed and up-draught (4-5 kg/cm)			Forced cold air	3-4			3 mo.	[illegible]	-After storage longer than 1 mo., oil yield reduced 1-2% and oil color turned dark. -Stab. cost U.S.$3.[illegible]/ tonne.	Yokochi, 1972, 1973 Japan	50 51
	U-shaped through mixer (pilot and industrial unit)	5% in-creased		100°C	2.5 min.	250 kg/hr. and 500 kg/hr.	Flash			Flash				6 mo.	O.K.	Stab. cost U.S.$3.75/ tonne for pilot unit	Barber, et.al. Fito, et.al. 1974 Spain	7 17
Screw extrusion	Screw extrusion	35% in-creased		135°C	1.5 min.		Flash			Flash				6 mo.	O.K.			
	Vertical expender	14.0 lb/hr.		250°F		475 kg/hr.	Oven				7-11			84 d.	not increased	-Crumb or rope products. -Agglomeration.	Anderson company	2
	Horizontal extender	22 lb/hr.	10 lb/hr	280°F										1 y. 1.5y.	7 → 7.4 7 → [illegible]	- Extraction rate increased.	William & Bear, 1965 U.S.A.	49

CHAPTER II

RELEVANT DATA FOR THE DESIGN OF RICE BRAN STABILIZING PLANT

In designing a small capacity, low cost rice bran stabilizing plant, the assumption should be made that the stabilized bran should have a shelf life of at least one month and the FFA content should not increase more than one percent from the initial figure.

It is presently known that, only heat treatment can effectively inactivate enzyme lipases. From the literature survey in Chapter I, the details of necessary figures and data were tabulated and shown in Tables 1 and 2 for dry and moist heat treatments, respectively. Therefore, either dry or moist heat treatment may stabilize rice bran, but the degree of stabilization may depend on the methods related to heating systems, duration, and degree.

A. DRY HEAT TREATMENT

Even though, dry heat was claimed to be a reversible destruction of enzyme activities (50) compared to moist heat, yet, dry heat treatment appears applicable and dependent upon the shelf life required, and the process is rather uncomplicated. In places where moist heat facilities might be unavailable, economically, and a stabilizing unit urgently needed, the dry heat treatment should be given priority.

Among the dry heat equipment discussed in Chapter I, it can be seen that, for effective stabilization, the equipment should have some means of agitating or stirring the rice bran. Screw conveyor or rotating drum may be the most suitable means technologically for this purpose. The bran could be stabilized for at least one month by treating for 20 minutes at temperatures between 105°to 110°C. The moisture content of the treated bran should be lower than 10 percent before storage. The cost of stabilization reported using an electrically revolving drum is U.S.$5 per tonne (46).

B. MOIST HEAT TREATMENT

Moist heat has been proved to be more effective than dry heat in stabilizing bran for longer shelf-life (43). For effective and economical stabilization, the process should be continuous and consist of an inactivator, a dryer, and a cooler. Moist heat processing equipment previously reported (Chapter I) included rotating drum and screw conveyor type inactivators, therefore, the inactivator should be equipped with some means of agitating or stirring.

Only 5 minutes exposure to live steam is required to inactivate enzymes in rice bran. However, when rice bran is injected with live steam, the moisture content of the bran will increase, thus, the steamed bran should be dried to less than 10 percent moisture content, especially when it is to be stored in tropical conditions.

The reported cost of stabilization of rice bran per tonne of Japanese plant (50) and IATA plant (7,17) were U.S.$3.4 and 3.75, respectively.

CHAPTER III

STUDIES ON RICE BRAN STABILIZATION AT ASRCT

Rice bran stabilization methods were studied at ASRCT for laboratory scale as well as pilot plant including the preliminary cost study of the pilot plant in order to explore the possibility of a commercial process for stabilizing rice bran.

A. LABORATORY SCALE

1. Stabilization by soaking in hexane

Hexane could not stabilize rice bran. After soaking raw rice bran in hexane, the FFA content increased gradually (52).

2. Rice bran stabilization by dry heat treatment

Rice bran was spread on tray and heated at 100-105°C in an electric oven for 1½ to 2 hours (24). The treated bran was stored at room temperature (28-30°C). It was found that the FFA content increased from 10.4 to 25.8 percent in 44 days.

In order to find the optimum time in stabilizing rice bran the study was carried out by choosing the heating temperature at 110°C and the heating time interval ranged from ½ to 4 hours (52).

The treated bran was then stored in polyethylene bag in laboratory (24°C during working hours). After 96 days storage, the FFA content increased from 5.6 to 19.6%, 4.8 to 17.5%, 4.7 to 11.3%, 4.6 to 6.8% and 5.8 to 13.2% for the treated time of ½, 1, 2, 3, and 4 hours, respectively. It was reported that drying time of 3 hours at 110°C gave the best result.

The effect of temperature of treatment on formation of FFA in rice bran was also investigated (11). Rice bran of 3.0 cm. layer thickness was heated at 110-150°C for 3 hours. The treated bran was packed in polyethylene bag and stored at the laboratory condition.

Moisture content of different temperature treated bran was less than 0.5 per cent. After storage for 2 months, the FFA content of bran treated at 110, 125 and 140°C changed from 2.8 to 4.8%, 2.3 to 3.0% and 4.6 to 5.0%, respectively. There was no change in FFA content of the bran treated at 150°C. The higher the temperature, the darker was the oil color, but there was no change of the quantity of oil extracted as well as the rate of extraction.

3. Rice bran stabilization by moist heat treatment

A can filled with rice bran was steamed in an autoclave at 100-105°C for 1½ hours (24). The treated bran was stored at room temperature (28-30°C). It was found that FFA content increased from 20.0 to 54.1 per cent in 13 days.

In order to get good contact between rice bran and steam, a layer of rice bran was saturated with steam (37). The treated pressure and time used were 0.3 to 1.6 kg/cm^2 gauge for 5-15 minutes, respectively. The treated bran was stored in cheese cloth bag in an "open" room (20-30°C, 40-90% humidity).

The moisture content of the bran during the storage period ranged from 8.5 to 10.0 per cent. The FFA content of bran treated at 0.3 kg/cm^2 gauge for 5, 10, and 15 minutes, increased from 2.6 to 38.3%, 3.1 to 6.5%, and 2.6 to 3.7%, respectively, after 50 days storage. It was reported that, rice bran treated with steam of 0.8 and 1.6 kg/cm^2 gauge, the hydrolysis of the oil was almost completely inhibited even though the steaming time was as short as 5 minutes.

The bran treated for 5 minutes with steam of 0.3 kg/cm^2 gauge and the bran treated for 15 minutes with steam of 1.6 kg/cm^2 gauge was further studied on the influence of heat on agglomeration (37). It was indicated that heat caused the agglomeration of the fine particles in the rice bran, and an intensification of the steam treatment, with longer treatment time and higher steam pressure, had a positive influence on the agglomeration.

The effect of storage containers and conditions on the formation of FFA of saturated steamed rice bran in layer of 3.5 cm. thickness at 1.4 kg/cm^2 gauge for 15-30 minutes was further explored (11). The moisture of the treated bran was between 12 and 13.9 per cent.

It is reported that the treated temperature and time used could not stabilized the bran, even though, the treated bran was packed in polyethylene bag and at low temperature (24°C, 60% humidity), unless the steamed bran was further dried at 105-110°C for 30 minutes. The moisture content of the bran treated in this way was reduced to 2.4 per cent, and the bran packed in polyethylene bag could be kept well for at least 3 months in air-conditioned room (24°C, 60% humidity).

B. PILOT PLANT SCALE

Only moist heat treatment process was studied for pilot plant scale (23). The pilot plant for batch, rice bran stabilization consists of a steam chest in which a trolly with 4 trays could be moved in and out. The steam chest was a cylindrical autoclave horizontal type, with a length of 150 cm. and a diameter of 100 cm. and the inside pressure was 3 kg./cm^2.

The study was designed to find the optimum condition for rice bran stabilization by varying: (a) steam pressure (0.7 to 2.0 kg/cm^2 gauge), (b) steaming period (7.5 to 15 minutes), and (c) rice bran layer thickness (1.5 to 6.0 cm or 5 kg to 20 kg bran/tray). The moisture content of the treated bran varied between 11.6 to 13.5 per cent.

The bran was packed in cheese cloth bags and stored in an "open" room at 23-32°C and 50-90% humidity. It was claimed that it is technically possible to stabilize rice bran by steaming it in an autoclave.

The proposed stabilized condition should be: (a) steam pressure: 2.0 kg/cm^2 gauge, (b) steaming period: 7.5 minutes, and (c) layer thickness of 3.0 cm. Therefore, the capacity of this unit was 40 kg bran/batch. The FFA content of the bran treated as above increased from 3.4 to 5.9 per cent in 20 days.

The effect of storage containers and conditions was studied on the formation of FFA of saturated steamed rice bran by using the above equipment (11). The thickness of bran layer was only 2 cm. (30 kg bran/batch). The treated pressure and time used were 1.4 kg/cm^2 gauge and 15-90 minutes, respectively. However, the treated bran was not packed in the same series of container and stored at the same series of condition for the different treatment times. So, it is quite difficult in interpreting the results. Thus, it was concluded that:

(a) Stabilized condition does not depend on steaming time only, but also storage container as well as storage condition.

(b) Steamed bran with 10 per cent moisture and packed in a cheese cloth bag is usually stabilized for 20 days in an "open" room of 60-90% humidity and 24-32°C temperature.

(c) Packing of steamed bran in polyethylene bag is recommended when moisture in bran is lower than 10 per cent, otherwise molds will easily grow and develop a high FFA content.

(d) Steamed bran packed in cheese cloth bag and stored in low percentage humidity place such as air-conditioned room (55-70% humidity) can be stabilized for at least 4 months.

(e) Steamed bran packed in plastic bag can also be stored in refrigerator of 4°C without deterioration for at least 6 months.

(f) Additional drying (½ hour at 105-110°C) of bran after steam treatment will ensure the bran stabilization, in this way bran can be stored for at least 6 months.

C. COST STUDY

A preliminary cost of two rice bran stabilization plants was studied (21,22). The first one was the batch type pilot plant experiment proposed by ASRCT group (23). However, the storage test of the treated bran has been conducted for only 20 days and it appears to have a definite increase in FFA content. In the second one, the Expandolex process, which needs greater power, greater pressure and a larger capacity unit was adopted (21). However, this plant appears, under present conditions, invalid for economical application in Thailand.

CHAPTER IV

PROPOSED RICE BRAN STABILIZING METHODS

The causes of rice bran deterioration are not only the enzymes present in the bran, but also microflora and insects. Heat has been claimed to inactivate enzymes and simultaneously kill microflora and insects. However, heat affects the nutritive value of rice bran, more or less, depending on the degree of the treatment, while it also destroys the natural toxicants which may appear in rice bran.

The assumptions in designing the low cost rice bran stabilizing equipment was made earlier that the stabilized bran should be stored safely for at least one month. The recommended FFA content should not increase more than 1 per cent from the initial value ... which should also be less than 5 per cent.

Based on the results obtained from the work done in different countries already reported in Chapter I,II and III, the conclusion as well as the recommendation can be drawn along the following lines;

A. Proposed rice bran stabilizing method for dry heat treatment.

B. Proposed rice bran stabilizing method for moist heat treatment.

C. In-line quality control.

A. PROPOSED RICE BRAN STABILIZING METHOD FOR DRY HEAT TREATMENT

Most workers attempt to stabilize rice bran while still lacking fundamental knowledge concerning the basic principles of rice bran stabilization. Dry heat treatment may not inactivate lipolytic enzyme totally (50), and available data does not assure complete and irrevesible stabilization of all enzymes concerned with rice bran deterioration. However, dry heat is capable of stabilizing bran -- under sufficient time parameters, especially in those places where a boiler and moist heat facilities are comparatively uneconomical to provide.

If the dry heat process is proposed, it should include drying and cooling procedures. Values of different dry heat parameters are recommended as follows:

(a) Temperature, 105-110°C;

(b) Time, 20 minutes;

(c) Moisture content of bran after stabilization should be less than 10 per cent;

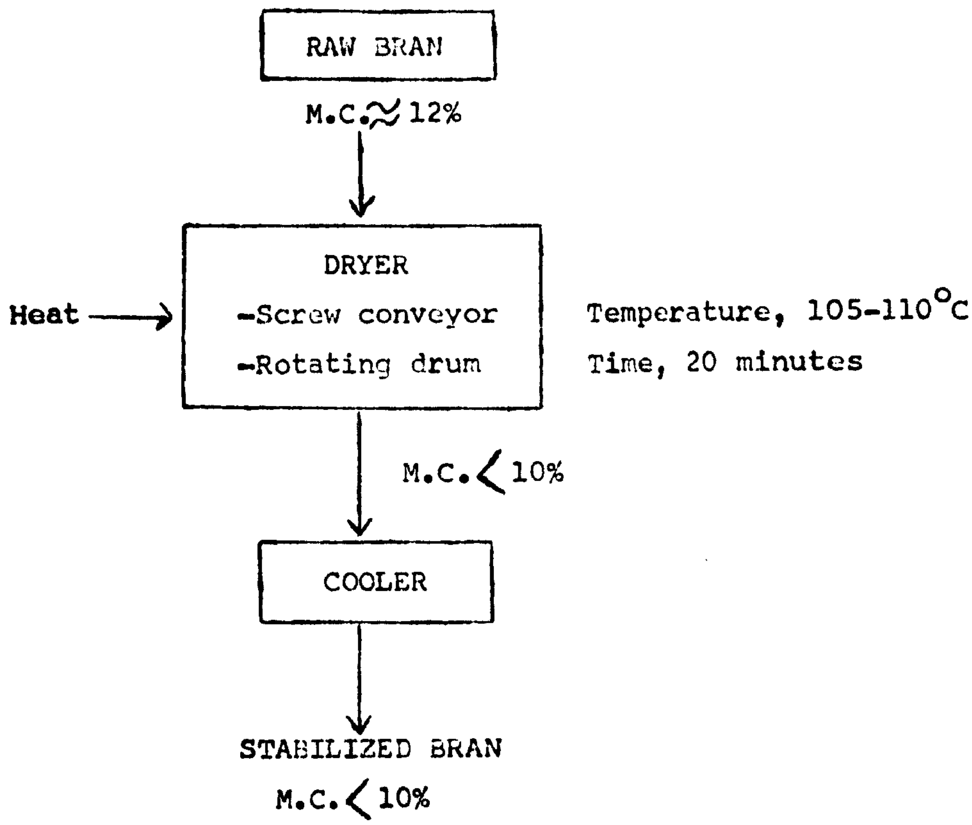
(d) While heating (drying), some type of agitator should be provided.

The flow diagram for dry heat treatment is shown in Figure I. Parameters selected are based mostly on the basic principles of rice bran stabilization discussed earlier (Chapter I, II,III and Table I). The temperature range 105-110°C and the agitator aided treated time of 20 minutes should not char the bran (4).

The only purpose of dry heating is to inactivate enzymes, not to dry the bran. In tropical country, the moisture content of the treated bran should be lower than 10 per cent to assist in the keeping quality of treated bran. In decreasing the temperature of treated bran down to room temperature, a cooling process should be employed. Furthermore, cooling may help prevent autooxidation and spontaneous combustion.

The drying equipment designed is equally important in order to heat the bran thoroughly. Any heating equipment with any type of agitator, e.g. revolving drum and screw conveyor may be recommended.

Figure I. Flow diagram of dry heat process.



B. PROPOSED RICE BRAN STABILIZING METHOD FOR MOIST HEAT TREATMENT

Moist heat has been proved to be more effective than dry heat in stabilizing bran (43). Moist heat treatment on the appropriate condition of moisture content, temperature and time achieved total irreversible destruction of all enzymes in bran oil deterioration ... also, destroying infestations by micro-organisms and insects (5,7,17).

Therefore, moist heat treatment under appropriate conditions, allows the stabilization of rice bran of excellent keeping quality and effects the nutritive value of rice bran very mildly.

Drying and cooling are also important steps in assuring the keeping quality of stabilized bran.

Assuming moist heat treatment is used, the process should be continuous and include stabilizing, drying and cooling phases.

Conditions necessary for satisfactory stabilization are well known, values of different parameters are as follows:

(a) Moisture, 16-18 per cent;

(b) Temperature, 100-105 ^{o}C;

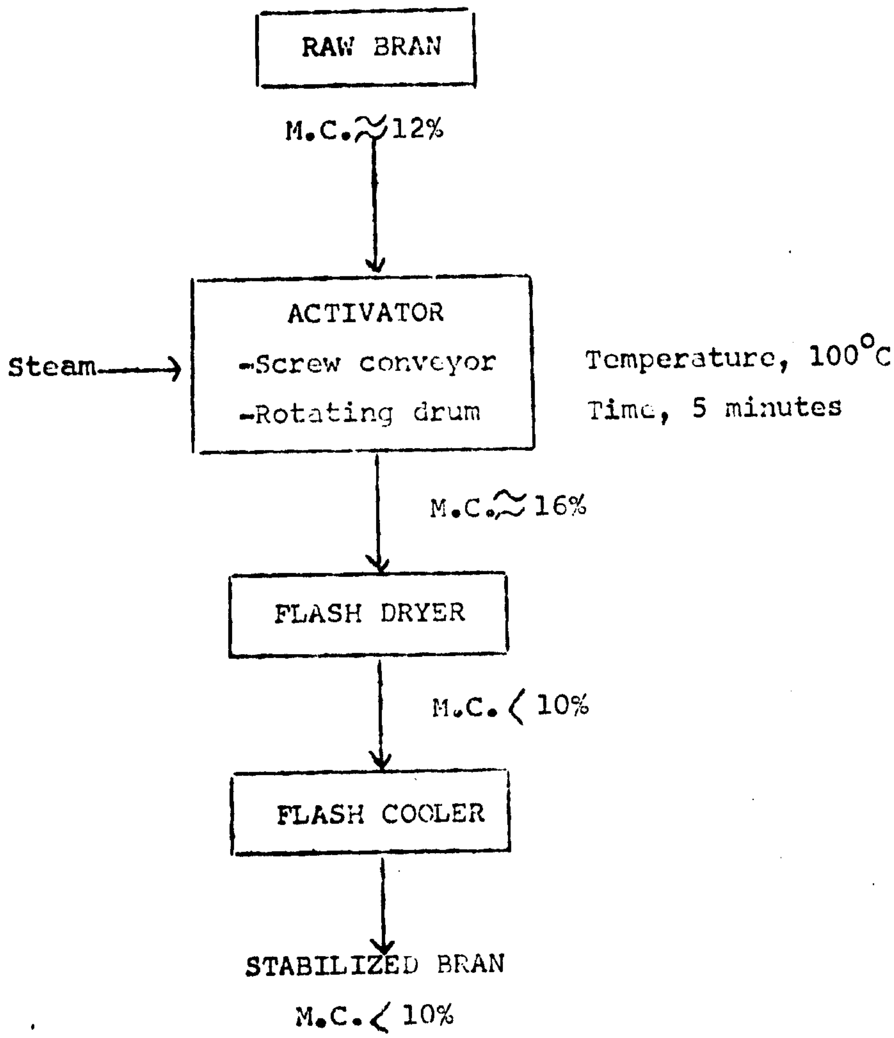
(c) Time, 5 minutes;

(d) Heating source, steam;

(e) Activator should be equipped with some type of agitator;

(f) Moisture content of bran after stabilization should be less than 10 per cent.

Figure II. Flow diagram of moist heat process.



The flow diagram for moist heat treatment is shown in Figure II. Parameters selected are based mostly on the basic principles of rice bran stabilization discussed earlier (Chapter I,II,III and Table II).

Flash drying should be most appropriate, since it is quite mild treatment as concern bran quality, it assures uniformity of drying and is suitable for continuous process. Again the moisture content of the treated bran should be lower than 10 per cent to assure keeping quality, especially in tropical conditions.

In bringing the temperature of treated bran down to room temperature, flash cooling is recommended.

C. IN-LINE QUALITY CONTROL

Among the enzymes found in rice bran, peroxidase is the most heat resistant, therefore, that process which inactivates peroxidase will have destroyed other enzymes damaging bran, e.g. lipases. Measurement of residual peroxidase activity has proved to be a reliable and practical method for assessing the effectiveness of stabilization. Available quick methods for peroxidase evaluation allows in-line quality control of the stabilization process, which is of outstanding importance to assure successful industrial practice.

CHAPTER V
CHARACTERISTICS OF STABILIZED RICE BRAN

Rice bran stabilizing methods were proposed in Chapter IV. In order to indicate the technological, bio-chemical and otherwise substantive feasibility and efficiency of the rice bran stabilization methods, laboratory and/or pilot plant tests were carried out.

Dry heat treatment was conducted in a steam jacketed kettle with stirrer, using 2 kg. bran per batch. The raw bran was heated at 105-110°C for 20 minutes. For the moist heat treatment process, a cylindrical autoclave (23) was used. The thickness of bran layer was about 0.5 cm. The steamed bran was then dried in a steam jacketed kettle with stirrer for 10 minutes at 105°C.

A. PHYSICAL CHARACTERISTICS

With regard to particle size distribution, simultaneous stabilization means some advantages. On the other hand, stabilized bran powder also contains a lower proportion of fine particles than the raw material as shown in Table 3 below.

Table 3. Effect of heat treatments on particle size of bran

ASTM sieve No. (mesh)	(%) bran retained on screen			
	Raw bran	Dry heat	Moist heat	
			Before drying	After drying
20	5.2	7.8	7.8	10.8
40	33.2	17.4	28.4	23.8
60	50.0	64.0	53.8	57.6
80	11.4	10.6	9.8	7.6
>100	0.4	0.2	0.2	0.2

B. PEROXIDASE ACTIVITY

Peroxidase activity is used as an index of rice bran deterioration. The method used in peroxidase determination is the modification of Vetter, et.al. (44). Peroxidase activity of the treated bran is shown in Table 4 below.

Table 4. Effect of heat treatments on peroxidase activity of rice bran

	Peroxidase activity (absorbance units per gram)
Raw rice bran	26.25
Dry heat treated bran	0
Moist heat treated bran, before drying	0
Moist heat treated bran, after drying	0

C. MOISTURE CONTENT

The moisture content of raw and stabilized bran is shown in Table 5 below.

Table 5. Effect of heat treatments on moisture content of rice bran

	Moisture content (%)
Raw rice bran	12.1-12.2
Dry heat treated bran	3.9- 4.3
Moist heat treated bran, before drying	14.3-17.2
Moist heat treated bran, after drying	7.1- 9.6

The result of moisture content parameter of rice bran after stabilization are shown in Figure III. It is clear that the bran, moisture content after stabilization 9.4-9.8 per cent, could be stored safely for at least one month, while the treated bran of 12.2-12.6 per cent moisture content could be kept for only 9 days.

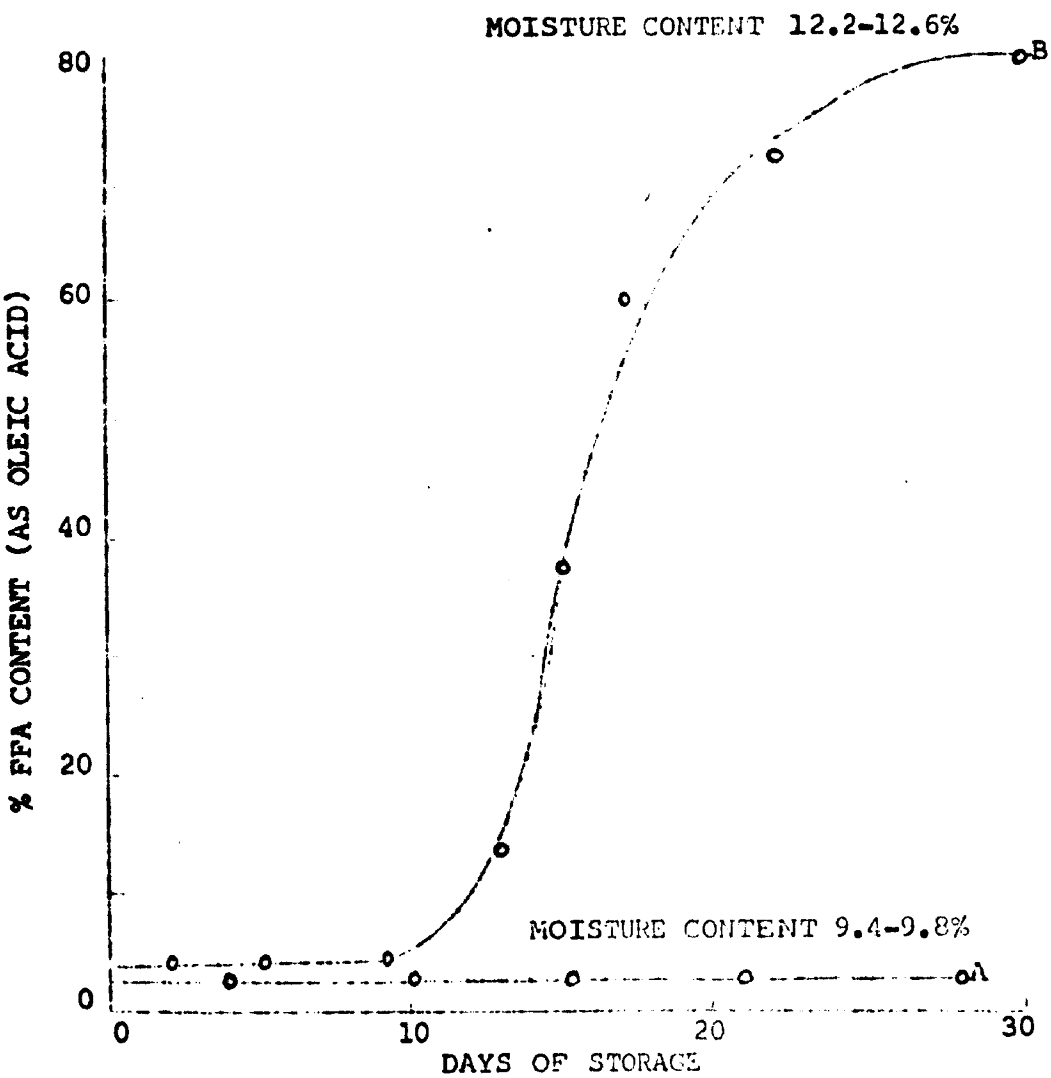
D. MICROORGANISMS

The process of stabilization destroys the microorganisms (Table 6). The destruction of mold spores is specially important in order to prevent their growth and lipase production.

Table 6. Effect of heat treatments on the microorganisms of rice bran

	Total count microorganisms/g	Molds/g
Raw rice bran	120-160 million	52-68 thousand
Dry heat treated bran	200-400	not detected
Moist heat treated bran, before drying	10-40	not detected
Moist heat treated bran, after drying	20-50	not detected

Figure III. Effect of moisture content of treated bran on FFA content during storage. The bran was kept in cheese cloth bag and stored in open room (temperature 24-30^{o}C; relative humidity 60-90%): (A) Bran steamed at 1.4 kg/cm^2 pressure, bran layer thickness 3.5 cm., laboratory scale experiment. (B) Bran steamed at 1.4 kg/cm^2 pressure, bran layer thickness 2 cm., pilot scale experiment.



CHAPTER VI

THE RECOMMENDED RICE BRAN STABILIZATION METHODS

Technologically speaking, it appears that, as a result of the present comparative study of rice bran stabilizing technologies, the moist heat treatment is most effective and, thus, should be recommended for use as the basis for designing and development of a rice bran stabilizing equipment. However, it is economically unattractive if such equipment is of small scale destined for development and use in developing countries where simplicity of operation and very maintenance are desirable. Therefore, a dry heat method is hereby recommended.

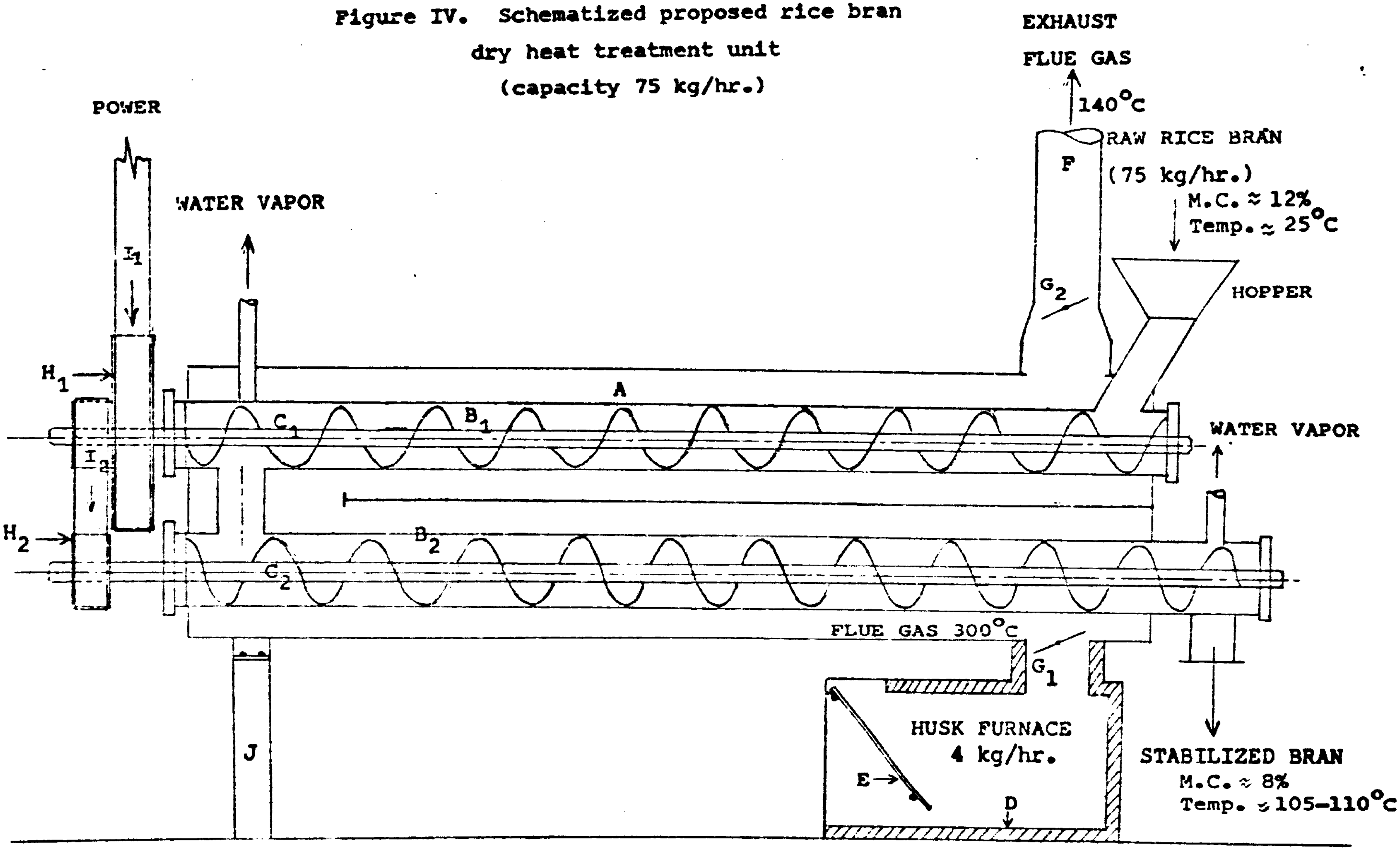
Since small sized rice mills processing less than 5 tons of paddy per day usually produce lower quality rice bran, e.g. a mixture of course and fine rice bran containing only (approximately) 13 percent oil, which is not economical if the rice bran is intended for oil extraction. If, such small quantities of rice bran may be readily stabilized -- to enhance keeping quality -- through simple toasting (dry frying) in a pan, with stirrer, over an open fire.

However, a larger sized rice mill (processing 5-10 tons of paddy per day) is the minimum sized unit which yields 300-600 kilograms of rice bran (per 8 hour day) of oil extracting grade. Thus, the practical and economical capacity of a rice bran stabilizing unit should begin at approximately 600 kilograms per day (75 kg/hr.) so as to correlate with the rice milling process.

Description of the recommended dry heat rice bran stabilizer

With a proposed 75 kg/hr. rice bran stabilizing capacity as the basis, it is expected that an inactivator utilizing indirect heat and mechanical stirring will be used as the stabilizer. (See Fig.IV). Bran produced by the rice mill, with approximately 12 percent moisture content at temperature at 25°C or higher, is fed into the drier at a rate of about 75 kg/hr.

Figure IV. Schematized proposed rice bran dry heat treatment unit (capacity 75 kg/hr.)



A = flue channel; B_1, B_2 = pipes; C_1, C_2 = shafts with conveyor blades;

D = fire brick; E = grade; F = chimney; G_1, G_2 = Dampers;

H_1, H_2 = driving pulleys; I_1, I_2 = belts; J = supporter

Bran fed directly into the stabilizer, from a mill hopper, should normally have a temperature higher than 25°C, thus, reducing the initial energy consumption needed to raise it to the 105-110°C level (within 20 minutes) required for stabilization. At the same instant of heating the moisture content is reduced to less than 10 percent (approximately 8 percent is used in the calculation).

The stabilized bran is discharged at the end of the heating tube and allowed to cool, naturally, to 70°C before being packed in gunny bags (60 kg/bag). The flow diagram of the recommended rice bran stabilizing process is shown in Figure V.

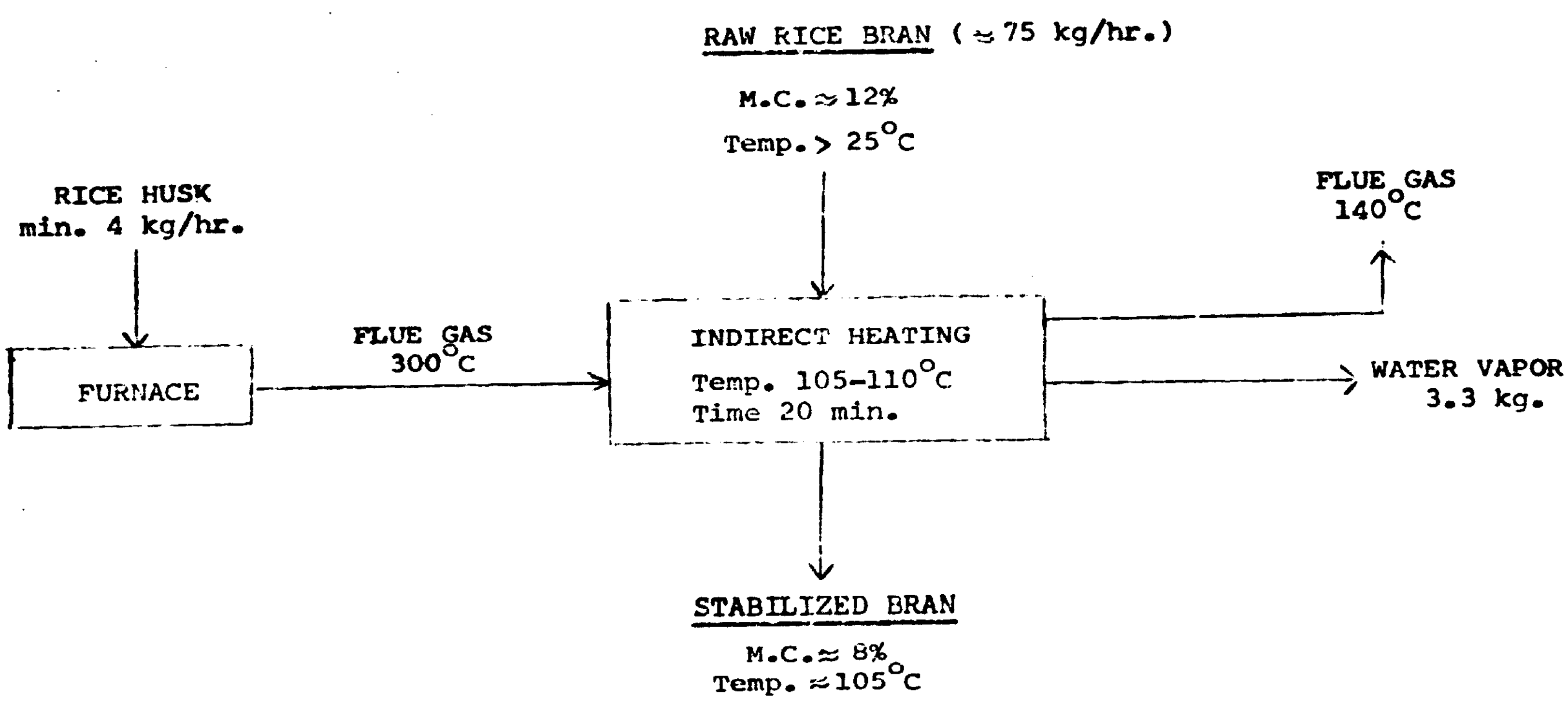
The material balance is summed up as follows:

	Rate	Composition
Feed	75 kg/hr. bran with 12% moisture content	66 kg. bran 9 kg. moisture
Product	1) 71.74 kg/hr. bran with 8% moisture content	1) 66 kg. bran 5.74 kg. moisture
	2) 3.26 kg/hr. water vapor.	2) 3.26 kg. water vapor.

With a screw conveyor inactivator heated by flue gas from a rice husk furnace, heating through a jacket, the stabilizer's energy balance is summarized as follows.

Rate of bran fed	75	kg/hr.
Maximum power	4.5	hp.
Diameter of screw conveyor	9	inch.
Length of screw conveyor	3.8	metres
Rate of heat required	4407.8	kg-cal/hr.
(heat loss by screw conveyor is negligible)		
Rate of heat required	5510	kg-cal/hr.
(25% heat loss by screw conveyor is assumed)		

Figure V. Flow diagram of the recommended rice bran stabilizing process (capacity 75 kg/hr.)



Temperature of flue gas in	$300^{o}C$	
Temperature of flue gas out	$140^{o}C$	
Heating value of rice husk	1400	kg-cal/hr.
Rate of rice husk consumed	4	kg/hr.

(heat loss by husk furnace and pipe is negligible)

As for the mechanical power requirements of 4-6 horsepowers a simple pulley and belt system tapping the spare power (20-40%) from the rice mill power system would be adequate and should be economically attractive.

CHAPTER VII

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