A STUDY OF THE POSIBILITIES TO ADD VALUE TO AND IMPROVE THE UTILIZATION OF RICE BRAN IN SURINAME – (ACP Project: 09 ACPSUR 007) (DRAFT)

May-June 2010	Adding value to raw rice bran by (heat) stabilization of rice bran, a pre-feasibility study

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CONTENT

1. INTRODUCTION

Paddy production in Suriname has been increasing gradually during the last years after being stable around 200.000 tons of paddy per year. In the autumn crop in 2009 about 27,000 ha was planted. This resulted in an annual production of approximately 200,000 tons of dry clean paddy that had to be milled for local production and export. Depending on the availability of irrigation water, improved water management infrastructure, the improvement of access to finance and credit, the development of cost of agriculture input and export rice prices, the planted acreage is expected to increase from 27,000 to 40,000 hectare per season from 2009 till 2018. This acreage will yield an annual production of approximately 400,000 dry clean paddy.

Traditionally Suriname exported more than 80% of its export product as husked rice (cargo rice) to the EU and some smaller quantities to the CARICOM and incidentally to other markets. Gradually however this has been changing as a result of the membership of Suriname to the CARIFORUM, the reform of the Common Agricultural Policy of the EU and the WTO-negotiations on world trade liberalization. The exports of milled rice of Surname increased during the last 5 years.

In December 2007 CARICOM countries signed an Economic Partnership Agreement (EPA) with the EU granting duty-free access for most products. For rice there was a transitional agreement for 2008 and 2009 granting duty-free access for all rice products for increasing quota for the CARICOM and OCT countries (187,000 and 250,000 tons). From 1 January 2010 CARICOM rice is granted quota-free and duty-free access to the EU markets. Recent calculations show that the production and export of cargo rice is less profitable than that of milled rice. The new situation will grant Surinamese rice improved access to the EU market for milled rice and the existing markets for white rice in the DOM-countries (Martinique, Guadeloupe and French Guyana).

During a short period in 2008 rice prices for milled rice on the international markets hiked to an unprecedented level of US $ 1,000 per ton, resulting in very high paddy prices. The same happened to raw material for feed production. During that period very high prices were paid locally for rice and rice by-products. But during 2009 and 2010 the rice prices declined to the level of 2007. Since oil prices and therefore prices of fertilizer and chemicals continue to increase the profitability and sustainability of the rice is seriously threatened because the margins of the millers evaporated.

The rice research institute ADRON of SNRI in Nickerie has been aware of these developments and during the last 3 years also millers are becoming aware that food safety, quality management and improved efficiency in the value chain as well as product development are crucial for the survival of the sector. Rice research has been focusing on all aspects of breeding and field production, but limited efforts were made to develop a post-harvest program. Predominantly as a result of the EU-Cariforum rice project, that was terminated in 2008, awareness was created by both ADRON and the millers with regards to this aspects. ADRON has therefore prepared a strategic plan to develop a post-harvest research program that is wholeheartedly supported by millers.

In de period 2008-2010, 7 rice millers have been awarded an ISO-22000 certification. Particular these millers are interested in a post-harvest program focusing on:

1. Increasing efficiency in milling operations by introducing new and more efficient technology and management systems.
2. Improving quality by extending their research efforts to the effect of variety and processing and handling on end user quality.
3. Product development, particularly by adding value to low value byproducts and waste.
4. Training and dissemination of PH-research and technical developments to the rice millers and exporters.

Communication and working relation between rice millers in general has improved considerably and they have pledged their support to the PH-program of ADRON. This is important since the economics of scale of the local rice industry does not allow individual millers to invest in R&D. And no industry can be sustainable if they do not invest in R&D. Therefore ADRON has to play a leading role in the Post-harvest rice R&D program based on the market trends, technologic developments and demands of the milling industry.

2. BACKGROUND

Rice is one of the most widely consumed food grains in the world. In Suriname irrigated fields are planted in 2 seasons. The raw rice, paddy, is harvested at high moisture content, dried and stored to be processed gradually during the season.

The dry paddy is processed in several steps. First by removing the outer seed layer by de-hulling the paddy producing husked rice, broken husked rice and husk.(seed cover).

The husked rice and the broken husked rice can be sold as such although that is less profitable. Rice is mainly consumed as cooked white rice since it is a basic food that is very neutral and has important non-allergenic characteristics. Therefore the rice is polished in 2 – 3 steps to remove the outer layers of the husked rice producing whole milled(white rice), milled(white) broken and chips and rice bran.

Rice bran is a byproduct of rice that is produced during the milling of husked rice (thus after removal of the husk/chaff) to white rice. Up till now the bran is used as raw material for the feed industry or is directly sold to cattle or poultry farmers who mix their own feed. About 8-10 % of the paddy grain is removed during the processing of paddy to milled rice.

Rice husk, rice bran , husked broken and milled broken rice have either no value or a much lower value than husked whole grains and milled whole white grains. By adding value to these byproducts or utilizing the waste products such as husk and straw, the value of the paddy can be increased. Since approximately 45% milled whole milled rice grains are produced when milling good quality paddy, 55 % of the milling outturn are by-products (broken and bran) and waste(husk) But the milled rice will contribute for approximately 85 % to the sales results per unit paddy. Increasing the net value of these byproducts and waste will definitely improve the profitability and therefore the competitiveness of the rice industry.

Three reports that discuss aspects of added value research are published during the last 5 years. The first two reports prepared in 2008 during the EU-Cariforum rice project in Guyana by IAST(9) and in Suriname by Polyformis(11), present an overview of the possibilities to add value to rice, rice byproducts and waste. The third report, a preliminary study on rice stabilization methods was prepared in 2009 by a BSc student of ADEKUS(8), who tried to establish the effect of simple laboratory stabilization methods on the safe storage period of rice bran. In none of these reports technical and economic information is presented that could motivate rice processing companies and other (agro)-industries to invest in added value projects for rice byproducts . Nor is a sector policy or strategy developed to promote such a development.

As a follow up to the EU-Cariforum rice project, in 2008 ADRON prepared a strategic plan for 20019-2014(1) and a work plan for 2009-2011(2). Post-harvest research and added value research in particular is part of these plans. Adding value to rice bran is one of the major activities in the planned post-harvest program. ADRON has tried to allocate funding for studies and pilot plants for bran stabilization and the utilization of stabilized bran for the food and pet food industry through the ministries of PLOS and HI, but was not successful due to the lack of funds. Therefore ADRON supports this study and consider it as the first step to create more awareness in the industry and the government for the importance of such a venture.

World rice production is more than 500 million metric tons per year and constitutes more than a quarter of all cereal grains. Rice is the staple food for a large portion of the world's population and has provided the nutritional basis for some of history's greatest civilizations. The peoples of Asia, South America, much of Africa, and portions of Europe, the Near East, and North America depend upon rice for daily sustenance. However, ineffective stabilization technology has caused the rice bran, which contains more than half of the nutritional value of every year's rice crop to be thrown away or disposed of as a low value animal feed.

Because of the difficulty of stabilizing rice bran, almost all of the 40 million metric tons produced every year has been discarded as unfit for human consumption. In effect, over half of the effort and resources used to cultivate rice throughout the world has been lost because of our inability to stabilize rice bran after it was milled.

Stabilization of the rice bran in Suriname increases the utilization of the bran and therefore the value. The stabilized bran can be used locally for high quality animal feed, or to produce rice oil.

Stabilized bran can also be used as a high value additive in the food industry. If the utilization of the stabilized bran in Suriname is limited because of lack of interest of the local feed and food industry, the bran may also be exported.

Exporting mills in Suriname who are already ISO-22000 certified, as a result of a project financed through the Ministry of PLOS during 2009, may be interested in investing in commercial bran stabilizing systems, once the feasibility has been proven.

The Stichting Nationaal Rijstonderzoeks Institute (SNRI) through its research centre the Anne van Dijk Rijstonderzoekscentrum Nickerie (ADRON) has identified the stabilization of bran and the introduction of commercialized bran stabilization systems as a logic result of the developments in the rice industry (increased food safety and quality awareness). This development will definitely trigger improved access of milled rice to the EU and DOM markets. The implementation of these systems, if feasible, will increase the profitability of the rice sector and will further stimulate the development of the food and feed industry in Suriname.

This study will provide the government, the industry and the financial institutions with the required information for decision making on investments and policy development on adding value to rice..

3. OBJECTIVES

The overall objective of the project 09 ACPSUR 007, is to develop a competitive Domestic Private Sector in Suriname that can contribute to a sustainable development, and to facilitate the gradual integration of Suriname into the regional and world economy.

More specifically this project aims to improve and enhance the competitiveness of the Agribusiness sector in general and the rice sector in particular, among others by:

a) Improving competitive capacity of the rice sector and its products, markets and by providing them the technology to add value to their byproducts.

b) Identifying the strengths, weaknesses, opportunities and the threats,(SWOT Analysis) of the agri- and food industry in general and the rice processing in particular to contribute to the development of new processing technologies in Suriname.

c) Assessing the potential for an integrated chain development (value chain creation) of the rice sector.

d) Identifying the opportunities for the enlargement of export of rice (by) products in general and intra trade between the industries in the feed and food industry in particular.

4. EXPECTED RESULTS

The study has to comprise the following components:

1. Data on rice processing and export earning of the agriculture subsector Rice.
2. Analysis on the existing and future losses during the commercialization of raw(not stabilized) rice bran under Surinamese climatic conditions.
3. Available processes and equipment to stabilize rice bran.
4. An analysis on the introduction of rice bran stabilization and the profitability of the rice industry.
5. A SWOT analysis on the development of these added value technology in the rice sector.
6. Markets (local, regional and international), where the product can be sold at attractive prices that are considerably higher than the existing prices for raw bran and prepare quality standards for raw material and finished product.
7. Standards for both raw and stabilized bran.
8. A strategy with concrete solutions and recommendations in terms of policy, market, products and organization in a training workshop session.

All findings and training materials shall be included into the report or on a CD/DVD.

5. METHODOLOGY AND RESULTS

The following activities were carried out:

1. The first step was the fact-finding to review and analyze the data on:
   - Rice processing and availability of rice bran
   - Rice bran prices in Suriname
   - Market demand for stabilized bran in Suriname and in the Caricom
   - Contribution of stabilized bran to export earnings and income of rice millers

2. After collecting information on the state of rice processing industry in Suriname and of rice bran stabilization in the literature and on the internet and meeting officials of ADRON and ADEKUS(Agro-processing faculty) rice millers and the major feed producer, a Logic framework was prepared.

3. Through these contacts and from the ministry of LVV and ADRON data were collected on bran utilization, bran prices, paddy production and export .

4. Based on the collected data the weaknesses and strengths of the rice processing industry in Suriname were reviewed and analyzed in terms of : production capacity, volume, product diversification, technology and organization.

5. Based on all aforementioned data the possibilities were indentified to be presented to the industry in order to create awareness of the possibilities of the development of added value products in the industry in general and for the high value by-product of (pet food and food grade)stabilized bran in particular.

6. By studying international research reports and through contacts with suppliers in the USA and Europe, existing methods and technical equipment to stabilize rice bran and produce high value added products from rice bran, both on laboratory and commercial scale were identified.

7. Based on the collected information and the meeting with the stakeholders, the opportunities were reviewed and analyzed, to introduce this technology in the rice sector and feed and food processing industry in Suriname.

8. With the collected technical and economical data, a pre-feasibility calculation for the installation and operation of rice stabilization units in rice mills was prepared.

9. Specific industries in Suriname and the Caricom where identified that may be interested to introduce this technology and utilize rice bran as an ingredient in their products.

10. Finally a strategy to introduce the production and utilization of high quality stabilized bran in Suriname was prepared and presented to representatives of the rice milling, feed and food industry together with the results of the study.

5.1. Desk research

Production and export data

Following production and export data were collected from the Ministry of Agriculture Husbandry and Fisheries (LVV).

Table 1. Paddy production(dry basis) and rice export data 2005-2009 compared with 1985

	1985	2005	2006	2007	2008	2009
Acreage harvested (x 1,000 ha)	74.9	45.6	44.2	42.1	43.7	54.5
Paddy harvested dry base(x 1,000 MT)	299.2	164.0	182.7	179.0	122.9	229.4
Av. Yield dry base (MT/ha)	4.0	3.6	4.1	4.3	4.2	4.2
Total export(MT)	131,672	35,873	41,374	52,499	52,641	51,941
Export milled rice(MT)	26,650	13,974	30,138	31,732	24,217	22.597
Export husked rice (MT)	87,132	20,992	10,941	16,567	27,199	28,758
Export broken (MT)	12,890	911	295	4,200	355	495
Export other(MT)	5,000 (paddy)	0	0	0	870 (parboil)	91 (parboil)

Source: Ministry of LVV. annual report 2008 , LVV-Statistical Department, Surexco

Processing capacity

A survey of 2008 of the milling capacity of rice mills during the EU-Cariforum rice project gave the following results.

The mills in Suriname clearly have an overcapacity considering the annual tonnage of app. 255,000 MT wet paddy to be transformed. There are 25 mills in Suriname of which 20 were operating in 2008.There is also an overcapacity in drying, storage and milling capacity.

Depending on the length of the harvesting period (8 or 12 weeks) the total drying capacity of the operating mills varies from 171.000 to 257.000 wet paddy per crop. Thus, based on then annual production of 255,000 tons of wet paddy in 2009, there is an annual overcapacity of 87.000 – 259.000 ton wet paddy . This results in a utilization factor of the existing dryers varying between 87 and 50 %.

The existing de-husking capacity of the mills per crop if operated at full capacity[1] is 354,000 tons dry paddy. Therefore the average utilization factor of the de-husking sections in the mills in 2009 was 32 %.

The whitening capacity of the mills per crop was 298,000 tons dry paddy in 2008 . The average utilization factor of the polishing section of the mills at full whitening production in 2009 was therefore 38 %.

The existing storage capacity is 103.00 ton dry paddy per crop including the concrete silo's in Wageningen. That means that at the existing production levels the total crop can be stored easily assuming limited milling during the crop. At the end of the crop theoretically the warehouse could be empty if all product can be sold and shipped at that time. Therefore the average overall utilization factor of the storage facilities is definitely around 50%.

In Suriname millers predominantly use inclined bin dryers for drying of the paddy. Only one mill operates tower dryers in combination with inclined bin dryers. Because the National Oil Company (Staatsolie)sells heavy oil to the millers for their burners at competitive prices compared to diesel oil, there was less pressure on the millers to transfer to husk as fuel for their dryers. So up to 2010 only a limited number of mills has installed husk furnaces in their dryers.

In table 2, the distribution of mills according to their milling capacity indicates that more half of the existing mills have a milling capacity less than 5 ton paddy/hr.

Table 2. Distribution of operational mills according to their capacity.

De-husking capacity	Numbe r
1,5- 2,5 t/hr	6
2,5 – 5 t/hr	7
5-10 t/hr	5
10 -15 t/hr	3

Source. Elmont. Cariforum-EU rice project, 2008

Seven medium and large mills are certified for the ISO 22000-standard in 2009 and 2010.

Most mills produce both husked and white rice. Some mills market their rice under their own brand name on the Caribbean market . The larger growers have integrated the whole production chain from cropping to marketing, but some still buy paddy from other farmers

1 If mills run 24/7 during 20 weeks per crop at full milling capacity.

if these farmers can supply good quality paddy or sometime they even purchase husked rice from the smaller mills.

Seasonal credit for farmers is mostly received from bank, but some millers also extend credit to farmers.

There is an active rice millers and exporters association. The only problem is, that only a small number of members is active in the organization. But the association is very active on policy level.

The general conclusion is that mills in Suriname had to compete during the last years for a limited quantity of paddy that is not sufficient to run their mills with an acceptable utilization factor . This results in inefficient processing and thus higher processing cost.

Rice products and by products

Rough rice is stored at a moisture content below 14 % and milled gradually during the two seasons in Suriname.

During the milling process the rough rice is first de-hulled by removing the hard protective outer layer. During that process husked whole grain (brown or cargo rice), broken husked grains and husk(chaff) are produced. Husked whole grains and husked broken can be sold as such. The bran is treated as waste and burned out in the open air. Husked whole grains and broken grains can also be milled by removing the pericarp, the tegmen and the aleuron layer. The milled white rice will contain most of the starchy endosperm. During milling the following products and by products are produced: whole milled(white) grains, large (1/2 and ¾) grains and small (< ¼) grains and rice bran and rice polishings.

The schematic drawing of the rice grain in the next figure explains the composition of the grain.

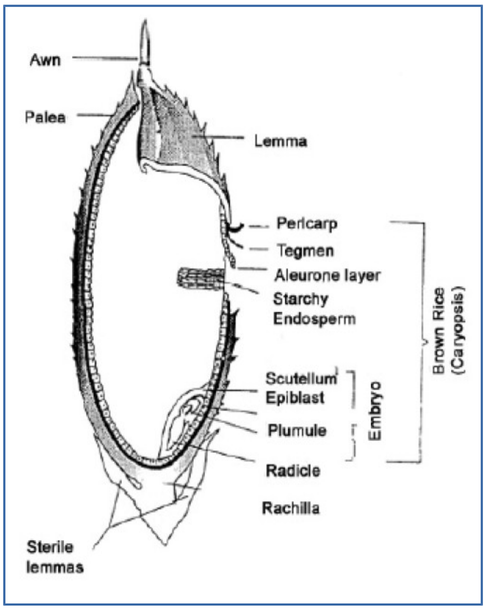

Fig. 1. Schematic drawing of rough rice grain

Composition of rice and rice byproducts

In research literature and handbooks (5) following reference data are presented describing the composition and nutrition value of the products and by products.

Table 3. Average composition of rice products and by-products

Components	Husked whole and broken grains(cargo)	Milled(white) whole and broken grains	Rice bran
Proteins (%)	7.1-8.3	6.3-7.1	11.3-14.9
Fats(%)	1.6-2.8	0.3-0.5	15-19.7
Macro-elements(mg/g)	4.8-15.1	3.0-5.5	40-87.9
Micro-elements(µg/g)	239-1,050	224-462	591-1,664
Vitamins(µg/g)	2,012-2,061	499-1,027	5,257-10,213
Energie (kcal/100 gram)	360-380	350-370	380-480

Source: ; Rice Chemistry and technology

It is easy to conclude that from a nutritional point of view rice bran is superior to milled and husked rice.

Rice bran nutritional value

Rice bran is a rich source of hypoallergenic protein, oil, dietary fibre, and nutrients essential to life. Rice bran is unique in the plant kingdom. It is the only major cereal that contains all of the essential amino acids, the necessary building blocks of all protein in the body.

Rice bran contains 18-23% oil, which is high in polyunsaturates and monounsaturates and is extraordinary in heat stability. Rice bran oil contains significant amounts of the essential fatty acids, linolenic acid, and linoleic acid that are necessary in order to maintain full health as well as a broad range of nutraceutical compounds that have been demonstrated to have remarkable therapeutic properties.

Nutraceuticals are natural compounds that have therapeutic effects on human systems. Some of these compounds, including a newly discovered complex of Vitamin E called "tocotrienols," and gamma oryzanol, which is found only in rice bran, have been demonstrated to moderate blood serum cholesterol and reduce triglycerides in hyperlipidemic individuals. Tocotrienols are being investigated for anti-cancer properties in a broad spectrum of different cancers. These compounds are potent antioxidants that protect the body from free-radical damage.

Rice bran also contains very high concentrations of B-complex vitamins. The B vitamins are vital to the health of the entire body but especially for the health of the nervous system and brain. Rice bran also contains beta carotene, a precursor of Vitamin A, and other carotenoids as well as most of the important minerals (low in Ca) and fibre.

Rice bran is an underutilized co-product of rice milling although it has the highest nutritional value of all rice products. The composition of the rice bran may vary, based on the variety and the milling process. In modern multistage mills like in Suriname, there are 2-3 fractions (the bran from the first and second milling step and the polish from the last (polishing) step). The combined fractions are contained in commercial bran.

The germ and the bran layers (about 10% of the rice kernel) removed during milling are rich in protein, lipid, fiber, minerals and B-complex vitamins, additionally rice has oryzanol, which has been demonstrated to be responsible for the lowering of serum cholesterol in humans. Oryzanol, a mixture of ferulic acid esters and triterpenoid alcohols, represent 20% to 30% of the unsaponifiable (non fatty) matter, or 1.1% to 2.6% of the total oil and 0.3% of the total bran.

On average commercial bran has 3.2 kcal/gram and contains 8% moisture and 20% to 30% dietary fiber, mostly insoluble. It also acts as an excellent source of B vitamins and minerals. The protein content of rice bran ranges from 12% to 20%. Protein digestibility and nutritional value are high with an protein efficiency ratio (PER) of 1.6 versus 2.5 for casein. It comprised 16% - 22% of fat and the fatty composition of rice bran is roughly 19% saturates (primary palmitic), 41% mono unsaturates (primary oleic acid), and 36% poly-unsaturated (primary linolic acid).

While the majority of rice bran is used in feed mills, recognition of rice bran's significant health benefits has increased its use in a range of foods beyond its current health store supplement status. Research from a number of sources, including the USDA, the University of Minnesota and the University of Massachusetts at Lowell, has shown the positive effects of rice bran on laxation, cholesterol reduction and renal calcium reduction. Isolation of an antitumor polysaccharide has also been reported. Research at the University of Massachusetts also indicates that rice bran and rice bran oil extracted from bran oil, reduces bad cholesterol (LDL). Rice wax, oryzanols and sitosterlol-all components of rice bran, have been shown to reduce serum cholesterol.

Bran degradability and stabilization

Rice bran is subject to such a rapid deterioration as a result of enzymatic reactions making it unfit for use in human and pet food. Sometimes even in rough rice enzymatic reactions occur if it is stored under unfavorable conditions (high heat and humidity).

The instability of rice bran has long been recognized. Nearly 100 years ago the lipase activity of rice bran was identified. As long as the kernel stays intact, lipase is physically isolated from lipids. De-hulling (husked rice) disturbs the surface of the surface of the kernel, allowing lipase and oil to mingle. This shortens the shelf life of husked rice when stored at high temperatures and humidity, thus the husked rice develops a less fresh and rancid smell when stored at these conditions for an extended period.

Under normal milling conditions, when brown rice is milled to white rice, the oil in the germ and a potent lipase enzyme found on the surface of the bran come into contact with each other. The lipase enzyme, causes very rapid hydrolysis of the oil, converting it into glycerol and free fatty acid (FFA) and quickly renders it unsuitable as a food or animal feed. As the free fatty acid content increases, the rice bran becomes unpalatable. At normal room temperature, the FFA concentration increases to 7-8% within 24 hours, and, thereafter, increases at the rate of approximately 4-5% per day. **Rice bran is unfit for human consumption when FFA concentration increases above 5%, typically within 12 hours of milling. Once the FFA concentration exceeds 12%, it becomes unsuitable even for cattle feed, the lowest economic use available to most crop by-products.**

Oils in intact bran contain 2-4% FFA. Once milled from the kernel a rapid increase of the free fatty acid content occurs. Lipase activity is highly depended on storage temperature and humidity. With rice that is stored under hot, moist conditions, the FFA content may increase 5-10% per day and about 70% in a month. Optimal temperature for lipase activity is 35–40 °C. Lower temperature reduces the rate of hydrolysis. No lipase activity occurs below freezing temperatures.

Rice bran also contains lipoxygenase and peroxidase, both having a negative effect on the oxidative state of the bran. Activity of these enzymes results in further degradation of the oil contained in bran, as reflected in increased peroxide value, decreased iodine value and increased thiobarbituric acid value. This causes rancidity in the bran, because the FFA produced by lipase activity are oxidized. This oxidative deterioration is responsible for the flavor and odor of rancid rice bran.

There are several methods developed to stabilize the bran by reducing the enzyme activity or deactivating the enzyme. Based on research, in rice producing countries, several commercial bran stabilized systems have been developed and are been delivered to the milling industry. These systems may vary in the degree of stabilization (extended storage time) and in the effect on the most valuable nutrients (protein and vitamins).

Heat, which will deactivate the lipase enzyme, serves as the basis for most stabilization processes. Parboiled (or "converted") rice is subjected to soaking and steaming prior to being dried and milled. This process softens the rice kernel and reduces the problem of lipase-induced hydrolysis. The bran produced from parboiled rice, however, is only semi-stabilized and can spoil in 20 days or less. The parboiling process also destroys most of the intrinsic nutritional value of the bran by destroying or leeching out the beneficial nutrients residing in the bran.

Several methods to stabilize rice bran were developed and tested. They include dry extrusion, wet extrusion(expansion), refrigeration, pH modification, chemical treatment and dry heat stabilization involving pan roasting, microwaving, heating in stationary dryers or fluid bed dryers. Long heating times during the dry heat stabilization however lead to process difficulties resulting in high microbial counts and insect infestation as well as heat damage to the bran and residual lipase activity may occur.

There have been numerous attempts to develop alternative commercial feasible rice bran stabilization processes that deactivate the lipase enzyme using chemicals, microwave heating, and variants on extrusion technology. However, recently several processors are claiming to have succeeded in creating truly stable rice bran while maintaining nutrient values. During this process, based on extrusion technology, the bran is sterilized, a process that kills the fungal and microbial spores, rendering the rice bran safe for human consumption or as an animal feed. Independent analyses have determined that these types of "Stabilized Rice Bran" has FFA and peroxide levels that are significantly lower than other rice bran immediately after processing and remain much lower over time.

Stabilization within 1 hr after milling is considered ideal for stabilized bran quality.

Commercial methods of stabilization

Producers of stabilized rice bran operating large commercial plants in different countries use extrusion stabilisation of rice bran. Although the main purpose of rice bran stabilization was, to:

- deactivate the enzymes that produces fatty acid (lipase) or oxidize the unsaturated fats, causing rancidity;
- stop degradation by microbes and insects.

But since several researchers discovered that rice bran contains has highly nutritional and physio-chemical substances that are also beneficial to human health continued research and product development resulted in additional options for the use of stabilized rice bran in health foods, special feed and as highly nutritional and therapeutical food additives in the food industry.

Since most of these substances are heat instable, long exposure to heat will have a negative effect on the nutritional value and health benefits of stabilized bran. Therefore systems were developed using technology that can deactivate enzymes without denaturing the other proteins, vitamins and physiochemical substances .

There are two methods of extrusion stabilization:

- Dry extrusion
- Extrusion cooking

Dry extrusion

Development of extrusion methods using retained-moisture heating have been successful. Dry bran of 10-14 % moisture is fed to an extruder which relies on frictional heat caused in the screw of the extruder to obtain temperatures of 130-150 ° C, Bulk density increases and moisture content decreases to 5-8%. Holding at extrudate temperature for approximately 3 minutes ensures stabilisation. The primary draw backs to dry extrusion include the following:

- Stabilized bran is a powder
- Colour of the stabilized bran may be dark due to high processing temperature
- Incomplete inactivation of lipase
- The equipment maintenance cost is high

Lipase activity is highly dependent on storage temperature and humidity. With rice that is stored under hot, moist conditions, the FFA content may increase . If inactivation of lipase is incomplete, maintenance of low moisture content during storage is required to maintain stability.

Extrusion cooking

Extrusion cooking is a cost effective stabilisation technique. Wet heating is more effective for bran stabilization than is dry heating. Lipase is activated at 3 minutes at 100 ° C. Equipment used in this system includes: steam cookers, blanchers, autoclaves and screw extruders with injected steam and water. Extrusion with steam injection and up to 10 % added water reduces the temperature required for lipase inactivation. Temperatures are reduced to 100 -120 °C. The product may be held for another 1,5 – 3 minutes before drying to stabilize moisture levels.

Bran expands as its exits the extruder and water flashes to steam. Porous pellets, also called collets are found to assist in solvent percolation during rice bran oil extraction. fines are agglomerated as well. Addition of water or steam to bran during wet extrusion requires drying after stabilization. Hot air is simple passed through beddryers. This increases the cost of stabilization, but the lipase inactivation is permanent, with less nutritional damage to the bran. The extracted rice bran oil is lighter in colour with lower refining losses. The stabilized bran may be stored for extended periods of time, but the oil extraction should be completed within one months for best quality crude oil.

Parboiling of rice is also an example of wet heat stabilization. Lipase is completely inactivated in rough rice by either autoclaving for 3-20 minutes or by parboiling.

Well stabilized bran has excellent keeping qualities. FFA content remains relatively constant for both stabilized or parboiled bran. Oxidative stability as determined by peroxide value is greater for stabilized bran then for parboiled bran.

Applications of stabilized rice bran for food and feed industry

Multiple products formulated with stabilized bran are currently marketed primarily through the Internet. Several animal feeds, particular horse feeds, claim improved performance, with the inclusion of stabilized rice bran in diets. Additionally fractionated [2] stabilized bran's are promoted for health benefits. Dry as well as wet fractionation processes are utilized.

Stabilized rice bran has many food applications in prepared foods, neutraceuticals and functional foods.

Some of the common food applications of rice bran are in snack foods, bakery products, cereals, crackers, pasta products, dough conditioners, beverages, gluten-free foods and medical foods. Rice bran containing beverage base can be used for isotonic drinks, ice tea drinks, enhanced juices, mineral supplements and sport beverages. Healthy meal replacement drinks made from stabilized rice bran are being introduced in the market.

Stabilized bran has shown no negative effect on the shelf live or organoleptic properties of foods containing rice bran as an ingredient. Stabilized bran also has no adverse effects on animal health or feed nutritional quality when fed at 60% of the diet in chicks or up to 40% of the diet op pigs.

Stabilized bran can also be used to produce high valued rice oil, high quality animal feed (pet feed, horse feed). The stabilization process improves the digestibility of the rice bran for certain animals and also improves the quality as such so that the utilization in pet food and for example horse feed is also possible and the nutritious value for poultry and cattle feed will be improved.The oil in stabilized rice bran has a marked softening effect on body fat and on the butterfat in milk. With attention to the oil content, rice bran is a valuable feed for all classes of livestock. The maximum

2 Bran from the different milling steps are fractionated bran's

amount advisable for cattle is about 40% of the total ration. For pigs, rice bran should not exceed 30-40% of the total ration to avoid soft pork; in the final weeks of fattening, lower levels must be used. Up to 25% can be included in poultry rations; double that amount has been used successfully in experiments. Rice bran that has not been defatted is a useful binder in mixed feeds

De-oiled rice bran can be used at higher levels than ordinary rice bran. Rice bran is often adulterated with rice hulls, as it should have a crude fiber content of 10-15%. The product containing large amounts of hulls should be sold under the name "rice mill feed", which is much inferior to rice bran. .

While the majority of rice bran from milling is used in animal feed, recognition of the significant health benefits of rice bran has increased its use in a range of foods beyond its current health food status. In the past, human consumption of rice bran has been limited, especially in the humid tropics, primarily because the bran spoils quickly. the effect of successful bran stabilization will create an enormous increase in the utilization of this product, especially for human consumption.

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In annex 5 examples of commercial products that are produced from stabilized rice bran or derivates form stabilized rice bran in the EU and the USA ,and marketed as such, are presented.

Factors affecting food and feed uses of rice bran

Flavor and color, functional properties, and nutritional properties are the three major factors determining uses and consumption of rice bran.

Flavor and color are influenced by the stabilization method used and the packing and storage conditions.

The **nutritional properties** are already discussed at lengths in other paragraphs of this study.

Functional properties such as protein extractability, solubility, water absorption, fat absorption , emulsifying capacity and foaming capacity are important factors to be considered for the use of bran in foods.

Bran availability in Suriname as calculated from production and export statistics

Data on rice bran production and sales during the last five years can be calculated from the production and export data assuming a average milling outturn of the paddy based of observations in mills and discussions during training sessions with millers in2008 (Elmont).

Following milling recoveries were used to calculate the availability of bran in 2009 based on current export levels and when all paddy is milled to white rice.

Milling outturn of paddy-dehusking

Dry paddy	100 %
Export cargo (4% broken)	55 %
Broken rice	20 %
Husk and losses	25 %

Milling outturn of cargo polishing

Export cargo 100 %= 55 % from paddy
Whole milled grains 70 %= 38,5 % from paddy
Large and medium broken 10 %= 5,5 % from paddy
Small broken 6 %= 3,3 % from paddy
Rice bran 13 %= 7,15 % from paddy
Losses 1 %= 0,55 % from paddy

Milling outturn of broken cargo polishing

Broken cargo 100 % = 20 % from paddy
Large and medium broken 55 % = 11 % ,, ,,
Small broken 30 % = 6 % ,, ,,
Rice bran 14 % = 2,8 % ,, ,,
Losses 1% = 0,2 % ,, ,,

Milled rice qualities

Export rice contains on average max. 15 % broken grains
Local consumption rice contains on average max. 25 % broken grains.

Milling outturn paddy to milled rice

Paddy 100 %
Whole milled rice 38,5 %
Milled mixed broken 16,5 %
Small broken 9,3 %
Bran 9,95 %
Husk and losses 25,75 %

Transformation rate from rough rice(paddy) to milled rice is therefore 0,643. For international statistical calculations (FAO, USDA) a rate of 0,63 is used for Suriname.

Year	Processing Alternative	Total paddy Produc-tion (ton)	Cargo export (ton)	Export milled rice-15% (ton)	Export broken (ton)	Local consump-tion milled rice-25 % (ton)	Remaining mix broken (ton)	Remaining small broken (ton)	Husk and losses (ton)	Bran availi-bility (ton)
2009	Actual	229,400	28,758	22.597	495	65.306	15,258	19,609	58,783	19,088
2009	Full white	229,400	0	46,281	495	65,306	14,087	21,334	59,072	22.825
1985	Full white	299,200	0	66.340	495	65,306	22,595	27,826	77,044	29,770
2018 est.[3]	Full white	400,000	0	123,553	495	65,306	30,645	37,200	103,001	39,800

3 Based on estimate of Mertens, 2008, EU-Cariforum rice irrigation expert

Table 4. Calculation of rice bran availability of present and future production scenario's

Source: R. Elmont, Min of LVV.

According to this calculation that is based on the official statistical production and export data of 2009 the consumption of milled rice-25 % in that year is to be calculated at 135 kg/capita. Taking into account that although part of the small and medium broken is also used for the feed industry and other industries , there is a remaining quantity of large broken that is not used for other(industrial)purposes that can be calculated as being part of the local consumption . The local demand as presented by the Staatscommissie report in 1987 are compared with these figures in following table.

Table 5. Evaluation of local demand

Product	Staatscommissie data(ton)	Calculated data 2009(ton)	Discrepancies (ton)
Bran	13.680 -18.360	19.088	
Broken for feed industry	19,000	19,000	
Broken for Brewery	660	660	
Broken for other industries	1,290	1,290	
Remaining large broken for human consumption	-	13,917	13.917
Domestic milled rice consumption	30,000	65,306	35,306
Total domestic consumption	30,000	79,224	49,223

Source: Staatscommissie Rijst., Elmont

These discrepancies could be caused by:

1. An increase of the turn-over stock at the end of 2009 with 49,223 ton
2. An increase in consumption per capita
3. Lower milling output of whole grain and total milled rice and higher losses than calculated.
3. Increased local industrial demand
4. Unregistered exports
5. A combination of these causes.

As a reference for this calculation FAOSTAT food balances for Suriname are presented in the next table.

Table 6. Food balances rice Suriname 1985-2007

	1985	1990	1995	2000	2005	2006	2007
Production	200,000	131,000	161,000	109,000	109,000	122,000	119,000
Import	0	0	0	0	0	0	0
Stock variation	25,000	8,000	-10,000	1,000	-3,000	-22,000	-15,000
Export	148,000	53,000	64,000	34,000	27,000	15,000	18,000
Domestic Supply	76,000	86,000	87,000	76,000	79,000	85,000	86,000
Feed	6,000	12,000	13,000	13,000	13,000	12,000	12,000
Seed	7,000	3,000	5,000	3,000	5,000	4,000	4,000
Processing	1,000	1,000	2,000	3,000	3,000	8,000	10,000
Other utilization	30,000	33,000	26,000	21,000	25,000	27,000	26,000
Food	33,000	36,000	40,000	35,000	33,000	34,000	34,000
Food supply quantity (kg/capita/yr)	86,8	88,7	92,4	75,7	66,4	67,1	66,4

Source: FAOSTAT

Other utilization in this table includes waste and the (negative) stock variation probably covers unexplained discrepancies.

Rice producer and rice world export prices

According to the FAO Statistical Yearbook 2009, the average rice producers price in Suriname for 2005-2007 was US $ 128/ton paddy. Only in Madagascar the producer price was lower , i.e. US $ 126 per ton. In the next table these figures are compared with the major rice producing countries. Even at the top of the market when world rice prices were rocketing over US $ 900/ ton paddy prices in Suriname were at a maximum US $ - 500/ton. During the 2nd half of 2008, 2009 and the first half of 2010 world rice prices dropped and so did paddy prices. During the last spring crop (2010) paddy prices were paid between US $ 240 and US $ 270. Based on the continuing decline in world market prices during the first half of 2010 lower raw rice prices are expected.

Table 7. Average rice producers price 2005-2007

Country	Rice producer price US $/ton
Argentina	287
Brazil	223
India	142
Italy	329
Madagascar	126
Philippines	212
Spain	295
Suriname	128
Thailand	191
USA	224

Source: FAO Statistical yearbook 2005-2007

Data from China, Vietnam en Guyana are not available.

World market prices of selected types of rice between 1985 and 2009 are compared in the next table.

Table 8. FOB World market rice prices of selected rice types

Year	Thai-2nd grade 100%	Thai parboiled 10%	US longgrain nr.2-4%	Vietnam 5%	Thai Fragrant 100%	Ordinary Pakistan Basmati
1985	188		361	-	-	172
1990	278		372	-	-	140
1995	336		371	-	-	-
2000	207		271	-	-	-
2005	291	285	319	255	404	473
2006	311	300	394	266	470	516
2007	335	332	436	313	550	677
2008	695	722	782	614	914	1077
2009	601	619	557	428	954	937
2010	528	531	519	395	825	998

Source: FAO

Although rice prices gradually declined after 2008, the prices in 2009 are still higher than before 2007.

International raw and stabilized bran markets

International market information about raw and stabilized barn can scarcely be found. The only information on raw bran was found on the site of USDA , Agricultural Marketing Services, Grain and Feed market services.

Table 9 . FOB USA ex factory prices raw bran and soy meal

Year	Raw rice bran-Fob Central Il. US $/ton	Soymeal Fob Central IL US $/ton
2004/2005	56.95	185,61
2005/2006	56.47	174,10
2006/2007	92,95	205,46
2007/2008	110.25	334,29
2008/2009	114.35	334,29
2009/2010	98.48	306,81

Source: USDA , Agricultural Marketing Services

Import prices raw material feed industry Suriname and selected Caricom (import)countries

Part of the imported bulk raw materials for the feed industry (maize, soya beans, soymeal and soybean cakes) can probably be substituted by stabilized bran that is of a standard quality. The import data are presented in the next two tables. Since there is some rice processing done in Jamaica and Trinidad local feed industry may already have some experience with raw rice bran as a raw material for their process. Same is applicable for Guyana where the potential supply of bran rice bran is much larger than in Suriname.

Table 10. Import and import soya prices in selected Caricom import countries

Year	Soymeal import Surinam (ton)	Soymeal import prijs Surinam US $/ton	Soybean cakes (soybeans) import Trinidad (ton)	Soybean cakes (soybeans) import price Trinidad US $/ton	Soybean cakes (soybeans) import Jamaica (ton)	Soybean cakes (Soybeans) import price Jamaica US $/ton
2004	8,114	342	75,108	255	121,111	157
2005	7,599	307	7,101(45,743)	383(358)	32,059	473
2006	6,774	268	9,680(9,096)	488(200)	78,398	240
2007	7,998	348	10,633	412	64,964	299

Source:FAOSTAT

Tabel 11. Import and import maize prices in selected Caricom import countries

Year	Maize import Surinam (ton)	Maize import prijs Surinam US $/ton	Maize import Trinidad (ton)	Maize import price Trinidad US $/ton	Maize import Jamaica (ton)	Maize import price Jamaica US $/ton
2004	19,730	157	47,495	279	193,024	149
2005	18,006	134	57,473	259	197,684	215
2006	15,562	144	65,790	269	304,129	144
2007	13,697	209	43,198	504	248,702	211

Source: FAOSTAT

5.2. Field visits

Utilization of processing capacities

In most rice mills the processing capacity is underutilized. The existing milling capacity is much higher than the actual rough rice supply, even though a lot of mils terminated their activities during the last 10 years. This is caused by the decline in planted acreage. Some mills who were able or willing to pay higher rough rice prices to farmers realized higher utilization factors. But in average even the highest annual purchases for a 15 t/hr mill was app. 500,000 – 600,000 bags of 70 kg dry paddy did not exceed a utilization degree of 52 % based on a 40 weeks continuous production schedule per year.

Bran production, sales and marketing

Taking into account that approximately 50% of the paddy production in Suriname was processed into milled (white) rice for local consumption and export to the CARICOM and DOM-countries (Guadeloupe, Martinique and French Guyana), local production of bran is estimated at 10.000 tons per year. The demand for bran from the local feed industry is estimated at 15,000-20,000 tons. This demand however is based on the assumption that the bran is of a standard quality with maximum amounts of foreign matters (husk, sand stones etc.), minimum amounts of protein, fat and fiber and free from spoilage by physiological degradation, insects and microorganisms. This is not the case in Suriname, since some millers do mix waste materials such as husk, paddy and other spillage after grading, with the bran that is sold. The bran deteriorates very fast under the humid tropical conditions in Suriname if it is not delivered immediately to the customer, what is not the case in Nickerie. It normally takes days and even weeks before the bran reaches the customer. There are also peaks in the production, since milled rice is only produced when there is demand in the market or when an order must be produced for an export shipping. This results in a very volatile market with prices varying strongly during one season.

The prices for rice bran as realized according to millers are presented in the next table.

Table 12. Realized average raw rice bran prices Suriname ex mills from 2007-2010

Year	Raw rice bran-ex mill SRD/30 kg bag	Raw rice bran-ex mill US $/ton	Price-fluctuation SRD/30 kg bag	Price fluctuation US $/ton
2007	14	162	10-22	119-262
2008	27	318	20-34	238-401
2009	15	176	9-17	107-202
2010	13	156	9-19	101-226

Source: Private mills

Bran prices have continued to decline after a short period of price increase in 2008 to a level that is the lowest since 2007. Current bran price is around SRD 8.50/bag (US $ 101/ton). According to millers and the feed industry, price fluctuations are not only caused by the world market prices of feed ingredients like maize and soya, but also by the irregular white rice production and thus, the fluctuating bran supply by millers . During periods of peak supply, supply is higher that demand, the bran stock will increase and the quality will deteriorate since the storage period will increase resulting in higher FFA-values and peroxide values. Furthermore the quality of the brains is not stable with regards to raw protein, raw fat, raw carbohydrates and raw fibers. This is caused by differences and fluctuations in milling degree and lack of standardization of the delivered product.

Actual data on domestic rice bran trading are not yet available. But based on the production and export data in tables 4 and 5 and estimated milling recovery factors there should have been 19,000 tons of bran and 19,000 tons of broken available for the feed industry in 2009 . Broken rice is supplied as small white broken and chips and as mixed husked broken. Husked broken is preferred by the feed industry since the quality is more stable and the deterioration is much slower than for bran. Though the fat, vitamin and protein is lower than in bran. Millers however will prefer to mill husked broken and export white broken if export prices for broken are attractive and the bran can be sold easily at good prices.

In general rice bran is actually considered by millers as a waste that may contain the low quality spillage, damaged product and byproducts that are not fit for human consumption and is sold as the lowest prices of all the products from rice processing. Therefore millers have not put any effort in sales and marketing of this product.

Rice bran is sold by mills:

- directly to the feed industry
- directly to cattle farmers
- to traders

Prices paid to the millers are influenced by raw material prices for imported maize, the supply and the quality of the bran.

Local bran demand

In meetings with the largest feed milling industry in Suriname it was evident, that there was an awareness that the use of rice barn and rice byproducts is to be preferred over use of imported raw material. Rice broken and rice bran are considered high quality raw material providing:

- the bran is fresh;
- the quality of the bran is stable;
- a reasonable standard can be accomplished by millers(protein, fat, foreign matters(stones, sand, husk); and
- the supply can be regulated.

If these conditions are met, the domestic demand for rice byproducts is estimated as follows.

Table 13. Estimated domestic demand rice byproducts from feed industry and poultry and cattle farmers

	Ton
Broiler feed	1,000
Poultry feed	12,000
Pig feed	1,000
Cowfeed	11,000
Total demand	24,000

Source: Feed industry Suriname

The feed industry did however indicate, that the quality requirements for raw material will be stricter, since standards for rice feed and therefore raw material for the feed industry will be required in the Caricom. The SBS is developing local standards now with the feed experts, cattle and feed industry based on the Codex Alimentarius Code of Practice for good animal feeding. This code refers to standards and good hygiene practices during the production of animal feed.

Rice millers in Suriname must therefore be prepared that in the foreseeable future rice bran and rice polish delivered to both the feed industry as well as the cattle farmers will have to comply to Caricom and national standards on:

- Moisture content
- Raw fat content
- Raw protein content
- Raw fiber content
- Ash content
- Fat composition
- Free fatty acid content
- Peroxide value
- Toxins content
- Residues of pesticides and herbicides
- Microbiological contamination
- Silica content
- Organic and non-organic foreign material

Based on analyses presented by the feed industry commercial bran composition in Suriname in 2009 varied as follows:

Moisture content :	6.1- 12.7	
Raw protein:	12.2-18.5	
Raw fat:	1.2-19.3	-
Crude fibers:	1.0-9.7	

This indicates the need for a standard for rice bran. This need was also expressed by the feed industry .

5.3. Logic framework

Based on the Terms of reference and the field survey a Logic framework was presented to the project management en attached to this report in annex 2.

5.4. Laboratory test bran stabilization

In order to illustrate the degradability and the effect of heat treatment on the lipase activity, two laboratory bran stabilization methods used in international research programs were identified. In cooperation with ADRON rice research station and one of the rice millers(N.V. Sunrice) and with the support of the chemical laboratories of ADEKUS(Anton de Kom University of Suriname) and Vitalo an initial laboratory test was performed to Illustrate the degradability of raw rice bran and compare it with bran stabilized simple heat treatments on laboratory scale to stabilize the bran.

For the first heat treatment one a commercial Sharp magnetron was used and for the second one an Express Equipment laboratory autoclave.

The methods used were already used in research tests (4,7 ,12). Because of the delay in the approval of this project the test started late and will be continued for several months, in order to establish the long term effect of the stabilization methods. Initial analysis of the first weeks is supposed to be presented in this study.

Sampling and sample preparation

Two fractions of bran were collected in the mill directly after the milling section. De first fraction was collected from the first (whitening) section. The second fraction of the rice bran came from the water polishing section. During a certain period of time bran of both the whitening and water polishing section were collected and weighed. Three samples were prepared: rice bran, rice polishing and a proportional mix of these two product, based on the originally collected quantities in the right proportion as in the commercial bran that is supposed to be traded by millers. These three samples were treated as follows:

Treatments

Treatment 0: raw, not stabilized, rice bran.

Treatment 1: bran stabilized with a magnetron for 3 minutes until the bran reaches a temperature of 107 ° C

Treatment 2: bran stabilized in a laboratory autoclave for 5 minutes at 110 ° C.

The samples were stored under different conditions:

1. In a freezer at app. – 19 ° C
2. In a conditioning chamber at 30 ° C.

Sample analysis

Starting at day 1, all the samples are analyzed periodically according to a fixed schedule every 14 days. In order to minimize the effect during transport to Paramaribo, to be analyzed at the University chemical laboratory and by Vitalo, the samples are stored in a freezer immediately until they can be transported in a cool box.

Some of the initial analysis are mend to determine the composition of the different bran fractions. Following values are determined at day zero to establish the nutritional value.

Vitalo

moisture content
raw proteins
raw carbohydrates
raw oils/fat
crude fiber

ADEKUS

proteins
raw oils/fat
peroxide value
free fatty acids
silica

These two stabilization systems are used since, according to the research literature, the bran produced with aforementioned methods were stabilized for at least 8 weeks and there are no laboratory extrusion facilities available in Suriname yet. Laboratory extrusion is considered to be the system that imitates the commercial system the closest on laboratory scale . Eight samples are analyzed In regular intervals of 7-14 days in the ADEKUS chemical laboratory.

Results

As soon as the final results of the chemical analysis and the visual observation of the different samples are all known after 8 weeks, they will be reported to interested parties.

From the collected samples of bran and the rice following factors were determined.

Weight rice bran : weight rice polish	0,65 : 0,35
Moisture content rice bran	9,2 %
Moisture content rice polish	13,1 %
Moisture content mix bran	10,7 %
Moisture content milled rice	11,4%
Whiteness milled rice	37,2
Milling degree milled rice	80

The first (control) samples were send for analysis to Vitalo and the control samples to ADEKUS . The treated samples are being stored during 8 weeks and analyzed every 2 weeks by ADEKUS. The result of the data at the start of the test could not be presented in time for this report.

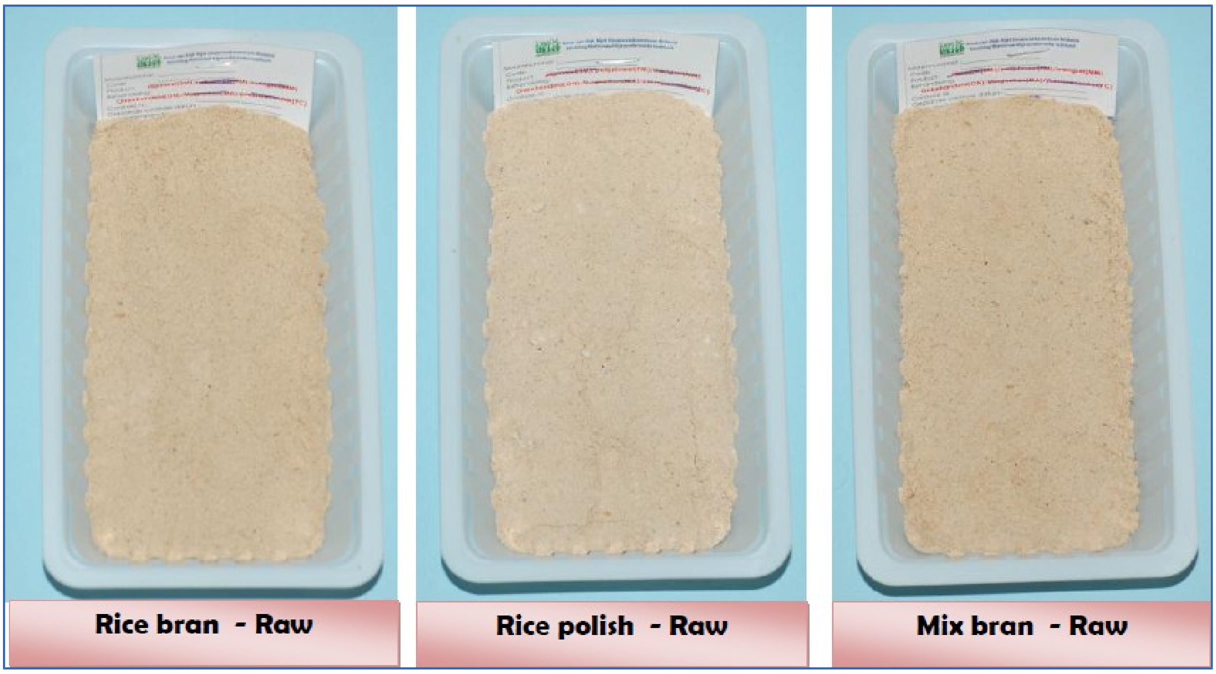


Fig. 2. Color of untreated raw bran samples

Fig. 3. Color of heat treated (stabilized) bran samples

The pictures in fig 2. and 3 show that the color of the stabilized bran is slightly darker than of the raw bran . During the 8 weeks test period, the samples will also be visually checked for changes in color and insects and for off-odors . At the end of the 8 week test period the different samples will be tested for microbiological contamination.

These results will give us a fairly good idea of the differences in degradation between the raw bran and bran stabilized in magnetron and autoclave . Also a second short test was performed to establish the speed and level of degradation (FFA and PV) during the first 48 hours. FFA and PV in samples raw mixed bran are analyzed after being stored at 30 ° C for 6, 24 and 48 hours.

Discussion of results and conclusions

The test results of the samples send to the ADEKUS laboratory and to Vitalo were not received in time to present in the report due to technical and logistic difficulties, out of the control of the consultant. On a later date the results will be presented to the SBF to communicate to the interested companies and institutions.

To illustrate the effect of stabilization on the FFA content and PV some data from tests performed with different stabilization treatments are presented instead.

1. ***LSU –stabilization test***

This test was performed at the LSU Agriculture Center in 2000 (7), with a rice bran sample obtained from Riviana Foods, Inc. Abbevile, LA. Composite samples were taken in a drum lined inside with a polyethylene bag directly from as the rice was milled. Each bag was tied and the drum was sealed and stored in a cooler at 5 ° C

<u>Stabilization treatments</u>

Extrusion Stabilization

A Food-Ex (Houston Texas) single screw extrude, model 1002 L was used . The rice bran was stabilized at a temperature between 125 and 130 ° C for 30 sec. and then held in the holding, transport auger for 3 min. The bran temperature in the auger ranged from 97-99 °C. The stabilized bran was air cooled at room temperature and collected in polyethylene bags.

Microwave stabilization

A commercial Option 3 microwave oven(Norris Industries, Los Angeles, California) operating at 2,450 MHz and 550 W maximum output power was used as the microwave energy source. The oven was preheated for 3 min prior to loading of the rice bran.

150 grams of raw rice bran at 21 % moisture content, was placed in a polyethylene microwave-safe bag (zipper-top) and exposed to microwave heating for 3 min. The temperature of the bran was 107 °C. The bran was removed from the oven and cooled to room temperature (24 °C). This process was repeated until sufficient stabilized bran was collected for the study.

Packaging and storage

Samples of raw, extrusion, or micro-wave stabilized bran were stored either in polyethylene zipper top or in vacuum-packed polyethylene bags and marked for storage times of 0, 2,4,6 and 8 weeks in a refrigerator. Samples were taken at 2-weeks interval for FFA.

Results

In table 14, the FFA values are presented for micro-wave heat and extrusion stabilized rice bran in vacuum packs and zipper-top bags.

Table 14. Effect of stabilization and packaging on FFA content of bran during storage in refrigerator

Treatment	Packing	FFA(% of oleic acid)				
		0 weeks storage time	2 weeks storage time	4 weeks storage time	6 weeks storage time	8 weeks storage time
Raw(Control)						
	Vacuum-packed	3.7	8.5	11.1	18.7	26.7
	Zipper-top bags	3.7	8.5	11.1	17.0	22.2
Microwave	Vacuum-packed	3.2	3.5	3.4	3.6	3.9
	Zipper-top bags	3.2	3.5	3.5	3.7	3.9
Extrusion						
	Vacuum-packed	2.8	2.9	2.9	3.2	3.2
	Zipper-top bags	2.8	3.2	3.3	3.3	3.3

As illustrated in this study, even at refrigeration temperature, the FFA content of raw bran increased in 6 weeks to a level that is not even acceptable for the feed industry. After 2 weeks the maximum level allowed for food applications (FFA=5) was also surpassed.

2. *Rice land Food Bran storage study*

In a Rice land Foods storage study lipolysis and oxidative deterioration of rice ban lipids were followed during storage, This study was designed to monitor changes in free fatty acid, peroxide value(PVP and odor of two bran types stored at two storage temperatures over a period of one year.

The extrusion-stabilized bran used was processed through a Wenger TX-80 twin screw cooker/extruder system at optimal stabilization conditions as according to Randal et al.

Parboiled rice bran was randomly collected from the bran stream .

The results of this study have confirmed previous studies, and may provide practical guidance for storage, packaging and utilization of bran as a food ingredient. This was indicated by relatively stable free fatty acid levels, confirming that lipase was inactive in both extrusion –stabilized and parboiled rice bran. Parboiled bran, however, proved to be much more susceptible to oxidative deterioration. The study also suggest that low-barrier packing material may be better for extrusion-stabilized rice bran so that volatile undesirable reaction product may escape instead of accumulating in the packaging to higher, detectable levels.

It appears that properly processed extrusion stabilized rice bran may be safely stored up to one year at $\leq$ 22 ° C in gas permeable packing.

The average of FFA values of extruder-stabilized and parboiled bran and the two packaging materials after 12 month was 4.6 %(22 ° C) and 13.0(38 ° C). After 6 months these values were 3.5(22 ° C) and 7.4(38 ° C).

PV (peroxide value) for extruder-stabilized bran at the average of the two storage temperature was stable after 12 months , 11.9 meq/kg oil basis(Poly), and 4.8 (foil). PV of parboil bran started at a higher level in month 0 (26,7) and increased in month 3 to 135.8(poly) and 90.2(foil). (Note: poly is low barrier and foil is high barrier packaging).

The maximum storage life for parboil bran seems to be 3-4 months.

3. Study ADEKUS

In 2009 a student of the ADEKUS(8) executed an orientation study on bran stabilization of rice. An unknown sample of bran was collected through ADRON in Nickerie . The sampling method as well as the transport timing and conditions were not recorded. The following stabilization methods were used :

- Bran stabilized by roasting in an open pan at different temperatures (80°C, 100°C and 114°C) and stored at room temperature
- Raw bran stored at room temperature.
- Raw bran stored in a freezer.

Samples were stored for 12 weeks and FFA was determined in 2 weeks intervals. FFA was calculated as a % of the bran weight and not of the extracted oil. This resulted in lower data for the raw bran after 12 weeks then can be expected according to other research reports.

However the results indicated that:

- FFA value in raw bran stored at room temperature after 12 weeks storage was 8- 9 times higher than at the start of the project.
- FFA value in raw bran stored in a freezer did not increase after 12 weeks storage.
- Heat treatment at 100 and 114 °C did gave the best stabilization effect after 12 weeks storage and were almost identical.

The results of the PV did not gave clear conclusions about the oxidative stability of the different treatments and was confusing, since instead of increasing as all literature indicates, the values decreased to zero for most treatments after 11 weeks storage. The recommendation that follow up tests with rice bran stabilization are needed is therefore correct.

5.5. Equipment supplier contacts

Since the commercial viable methods to stabilize rice bran with larger capacities is using extruder technology suppliers in different countries were contacted who supply these systems for food and feed processing installations. This resulted in quotations for laboratory units, a smaller commercial unit for a pilot plant and larger commercial units.

Commercial equipment

Three major international suppliers of commercial extrusion systems were approached for technical information and cost prices for commercial bran systems. Alternative and cheaper solutions from reliable suppliers in China, India , Brazil and other countries could not be identified yet.

The suppliers contacted where:

1. Wenger, USA
2. Amandus Kahl, Germany
3. Buhler Miag, Germany

Laboratory equipment

Also contact was made with Brabender in Germany for the supply of laboratory extruders . The factory was visited and some possible options for a laboratory test unit were discussed. Possibilities to test bran with an existing system during August 2010 were discussed with the sales representative. The technical expert is than present to discuss technical details and perform some test with rice bran samples.

An alternative supplier for the laboratory extruder may be LabTech Inc. in Thailand. However they do not deliver laboratory extruder systems for the food industry.

In paragraph 7 the laboratory and commercial systems are discussed . In Annexes 7-9, the quotations and technical infromaion of all the quoted systems are attached.

5.6. Mini-workshops

In two mini workshops, the results of this study are presented and discussed. Potential investors and industries interested to adopt the technology in their rice mills or use stabilized rice bran in their products will be invited.

The first workshop will be organized in Paramaribo and will focus on : members of SBF, food industries, bakeries, banks, food engineers and consultants, representatives of business organizations, research institutions, university, technical educational institutes, ministries and other government agencies.

The second workshop will be held in Nickerie in cooperation with ADRON and VRE in the ADRON meeting room. Millers, research staff of ADRON, staff of the Ministry of LVV and local banks will be invited.

Comments and input from these workshop will be presented in a workshop report and if necessary the proposed strategy will be adapted if required.

6. OVERVIEW OF THE RICE VALUE CHAIN IN SURINAME

6.1. SUPPLY, DEMAND AND MARKETING OF RICE AND RICE BYPRODUCTS

Marketing

The collected data during the desk research and the field visits, indicated that world rice prices, although declining after a sharp peak in 2008 (table 8), are currently on a level that is much higher than at any time during 1983-2007. Only during the period of the OCT arrangement, when ACP rice could be exported free of import duty to the EU through Oversea Territories of EU countries in the Caribbean, high prices were also realized.

But these high prices did not result in higher farmer prices, and the acreage increase in 2009 with roughly 25,000 ha of which app. 5,000 was from the Wageningen polder that was planted again by small farmers. The autonomous growth in acreage in 2009 compared to 2008 was therefore only 3,000 ha.

Exports also continued to decline indicating an increase in "unregistered exports" as calculated in table 6 and 7.

Most millers/exporters did not have a properly staffed marketing and sales department since their operations are too small to hire qualified personnel. Marketing and trading is therefore done through international traders, agents or brokers. There are only 2 millers/exporters that have operations outside Suriname and in the EU. These millers are more aware of international developments. The same is valid for the development of new or added value products. Although technical facilities of the dryers and mils are improved during the previous 5-10 years the products that are marketed did not change, i.e. cargo (husked) rice, milled (white) rice with broken percentages varying form 10- 25 %, cargo broken, white broken and raw rice bran.

We can say that the industry did not have the technical and commercial capacity to market their products effectively and efficiently and introduce new technology and products without outside support. There is no bundling of marketing efforts to reduce cost and increase effectiveness.

Exporters complain that they cannot compete on international and Caricom markets since Surinamese rice is offered at too high prices, according to the traders and sales agents. But the facts are, that although rough rice prices in Suriname are one of the lowest in the world (Annex 3), the milling industry is not operating very efficient since milling capacity in most mills is underutilized, packing systems are also used inefficiently and only modernize slowly, and individualized procurement of consumables, marketing , sales and exports lead to high processing and marketing cost.

The main objectives of the milling industry to tackle this problem should be:

1. Lowering the processing and marketing cost by improved efficiency and cooperation between mills.
2. Increasing the sales revenues of rice and rice by-products.
3. To invest in proven technology to utilize waste and add value to byproducts .
4. To cooperate with national and international rice research institute studying new technologies and participate in the operational testing and introduction of new technologies.

For the development of waste utilization and added value products the rice research station ADRON in cooperation with ADEKUS, can play a crucial role to assist the industry with relevant research projects.

Demand

The demand in the Caricom and the French Overseas Territories for white rice is much larger than the supply from both Suriname and Guyana. Total net import in the Caribbean, excluding the

OCT(Overseas Countries and Territories of the EU) is more than 1,2 million tons per year on milled base. There is also a demand for milled rice in the EU if logistics, quality and pricing is competitive. There is also a reasonable demand for good quality broken rice for industrial use in Suriname and the Carribean .

Looking at the collected data and field information there is no doubt about it, that there is a substantial demand for stabilized bran from the feed industry in Suriname and probably in the Caricom if a standard quality can be guaranteed . The demand for food grade and pet food grade bran can only be developed if stabilization test can produce stabilized rice bran in small quantities that can be used in tests in the food processing industries. They too will have to develop new products, unless the stabilized bran can be used as a substitute for other high fiber additives in existing products. Industries that could benefit from these developments are among others : bakeries, meat industry, diary industries and producers of puffed and ready to eat cereals and crackers .

If the stabilization of rice can be introduced successfully and increase the value of this byproduct significantly , milled rice production will increase and based on the calculations in table 4, annual bran production will increase at current level of rough rice production to 22,00-23,000 tons per year and increase gradually up to 2018, if external conditions for rice production are improved , to 30,000-40,000 tons.

6.2. Rice milling industry

7 millers are ISO-2200 certified and apply a food safety/quality management system. The remaining mills are interested to introduce at least a food safety system based on HACCP principles in their mil in the foreseeable future. Since mills are more quality and food safety oriented , at least the 7 certified mills have potentials to address s the introduction of added value processes in their mills. Some mills have already expressed interest in the parboiling, rice oil production and other products. But they are some constraints that have hampered the introduction of these technologies. For parboiled, the price difference between milled rice and milled parboiled rice has decreased, reducing the profit margin as the world market prices in table 8 illustrates. The constraint for the introduction of rice are the limited quantities of bran available (the smallest available oil mill has a capacity of 50-100 tons per day, i.e. 12,500 – 25,000 tons of bran per year. Availability and collection are here the problem . Therefore bran should be stabilized before its collected by any industry. By increasing the shelf life of rice bran the marketing possibilities of the miller are improved. Larger stocks will not immediately lead to a sharp decline in prices.
Since the technology involved in bran stabilization is much more complicated than the milling technology currently used, and very specific laboratory facilities will be needed for the development of stabilization receipts (product development) and process control, individual millers will not be able to develop such an operation without outside help. If ADRON and ADEKUS can develop facilities and knowledge of the appropriate technology they can be supportive to the rice industry in developing different grades of stabilized rice bran to be marketed locally and in the Caricom.

Because the degradation and spoilage of the raw rice bran will occur much faster in the humid tropics of Suriname than in more moderate climates, the window of opportunity to keep the quality of the raw rice bran at the highest possible level, to be able to produce a wide spectrum of products from rice bran (from high quality feed to functional foods and neutraceuticals), is very limited.

Therefore mills will have to adapt their processing facilities and operation is such a way, that:

- the rice bran cannot be adulterated by mixing waste material and low quality products;
- the whole process is aimed at producing food grade products in the mills;
- rice ban collection must be organized in such a way, that different fractions can be collected separately so the miller can supply stabilized rice bran from different fractions and also different mixes, depending on the demands from the feed and food industry;
- processing must be organized in such a way, that the milling degree and therefore the setting of the machines doe not vary very much and the chips, broken, husk and foreign matters are minimized.

So beside the required investment in the stabilizing equipment, the individual mills should invest in additional milling equipment and quality management to guarantee a standard raw material .

Since this requires organizational and operational changes in the mills, we may assume, that the ISO-22000 or HACCP certified mills will have an advantage over the other mills since they already have a food safety and /or quality management system in place. Mills who adopt this new technology will be able to procure husked rice from the smaller mills if they introduce a food safety system, and the certified millers can utilize their stabilizing equipment and modern packing facilities more efficiently. It may also be possible that larger mills purchase rice bran from the smaller mills if they can monitor and control the deterioration of the bran from those smaller mills properly. If millers who operate a rice bran stabilization plant pay better prices for the cargo rice, it may be interesting for small mills not to mill their cargo rice, if they cannot stabilize their bran, but sell it at a higher price, to mills with a bran stabilization unit.

Therefore the introduction of this technology will cause a revolution in the rice industry and the food industry in Suriname when a standard method to produce and guarantee standardized stabilized bran products is successfully developed.

6.3. EMERGING TRENDS

Awareness in the rice milling industry towards improved management systems and adding value has steadily been growing. Packing installations are improved and food safety and quality management systems are introduced and implemented.

Mills have also expressed interest in several value added products like parboiled rice, rice bran oil, alternative use of husk as fertilizer and rice flour from broken rice .

The international trends in foods using more and more traditional products in consumer food products that has health benefits has gained momentum. A recent development is the use of several tropical fruits in fruit juices. Consumers in Suriname are also more aware of the development where some product have been proven in clinical studies to have therapeutical effects on, among others, the prevention of heart disease, cancer, osteoporosis and high blood pressure. An local example is the recent development of Noni juice.

Although, some of these products , are grown in Suriname, the industrial production is hampered because the local production is limited, making it difficult to introduce modern processing plants on a feasible scale. If these products are produced on too small a scale they are not competitive and can only be sold in health food shops .

For rice bran stabilization we do not have that problem, because the quantity of raw material is sufficient to start several commercial bran stabilization and processing units in Suriname and this quantity can only increase. The availability and projected increase of the quantities rice bran should therefore not be seen as a threat, but as an opportunity. Awareness should be created within the food industry and consumers in Suriname and the Caricom should be informed , that rice and rice byproducts offer additional health benefits that go beyond the normal nutritional value.

6.4. Key issues in the milling sector

The following key issues are therefore identified in the rice milling sector in Suriname.

- Rice field production has been declining for decades and has only recently slowly been recovering, limiting further industrial development.
- Rice milling capacity is underutilized, leading to higher processing cost that leads to uncompetitive products.
- No value added to rice and rice by products .
- Waste of rice production is barely utilized.
- There is a lack of structured product development research .
- Limited consumer awareness of the additional health benefits of rice and it byproducts.

These issues should be addressed in a national agro-processing and a national rice policy and the necessary institutes should be supported to develop and support added value projects initiated by the industry.

6.5. SWOT-analysis

Based on the global value chain analyses of the raw material supply , processing and the marketing of rice and rice products, a SWOT is prepared to establish how the industry is prepared to introduce rice stabilization (Annex 6). Based on the SWOT a strategy for the introduction can be prepared.

To be able to compensate the weak points , counter the threats and utilize the strengths and opportunities , following conditions are crucial to develop a feasible and sustainable stabilized rice bran production.

- The Government should commit to provide the necessary funds for preliminary research by ADRON/ADEKUS to develop and test bran stabilization installations and recipes and to perform a marketing study.
- The Government should also commit to finance additional laboratory equipment for ADRON to facilitate process control during stabilization tests and to assist the milling industry by providing quality certificates for raw bran and stabilized bran
- ADEKUS should speed up the implementation of a complete laboratory for food analysis and testing in order to assist the industry to develop products from agricultural product and byproducts such as rice and rice bran

- A PPP project steering group should be installed to monitor the project and in which the VRE, the Government and ADRON/ADEKUS will participate
- VRE should set-up a special commercial rice bran stabilizing entity where all members participate as a shareholder to manage the company or individual millers should commit their participation in the project.
- The industry will have to develop standards for raw rice bran and stabilized bran food grade bran for the feed and food industry as well as stabilized bran and bran derivates for consumer products.

6.6. Rice bran composition, degradability, standards and utilization

In this study it is not possible to do a complete analysis of the composition and degradation of commercial bran produced by all mills by determining:

- Composition and nutritional value
- Rancidity (FFA, PV)
- Foreign material (sand, stone, etc.)

ADRON/ADEKUS plan to continue the analysis of the commercial rice bran as planned in the rice Post-harvest program of ADRON. With these analysis results the mills can be advised how to improve the quality of their raw bran and the rice milling industry can be assisted to establish quality standards for raw and stabilized bran for both feed and food applications

Required stabilized bran composition for feed applications

The feed industry has indicated that the following nutrient parameters are important when analyzing rice and rice by-products to be used in animal feed.

General

- Moisture
- Raw proteins
- Raw fats
- Carbohydrates (Ewers)
- Raw ash
- Raw fiber

Minerals

- Calcium
- Fosfor
- Natrium
- Chloor

Fatty acids

- C 18:2 Linolic acid

Digestibility

- ADF (acid detergent fiber)
- NDF (neutral detergent fiber)
- NSP (Non Starch Polysaccharides)

Amino acids

- Lysine
- Methionine
- Cystine
- Tryptofaan
- Threonine

Important for the digestibility of the rice bran are the factors ADF, NDF and NSP.

Acid detergent fiber (ADF) (13):

This value refers to the cell wall portions of the forage that are made up of cellulose and lignin. These values are important because they relate to the ability of an animal to digest the forage. ADF consists of cellulose, lignin, bound protein, and acid insoluble ash portions of a feed. Since these constituents are quite indigestible, ADF is a negative indicator of energy level in forages and grains, i.e., as ADF increases, digestible energy is decreased. Early-cut forages contain less ADF and a more energy than late-cut forages. Legumes generally have lower ADF and a higher net energy than grasses at comparable stages of maturity

Neutral detergent fiber (NDF)(13):

The NDF value is the total cell wall, which is comprised of the ADF fraction plus hemicellulose. Neutral detergent fiber values are important in ration formulation because they reflect the amount of forage the animal can consume. As NDF percentages increase, dry matter intake will generally decrease. Many laboratories analyze for ADF but may not include NDF values.

Lignin(13)

Lignin is the prime factor influencing the digestibility of plant cell wall material. As lignin increases, digestibility, intake, and animal performance usually decrease and the percent ADF and NDF increase.

Non starch Polysaccharides (NSP)(13):

Those polysaccharides (complex carbohydrates), other than starches, found in foods. They are the major part of dietary fiber and can be measured more precisely than total dietary fiber; include cellulose, pectin's, glucans, gums, mucilages, inulin, and chitin (and exclude lignin). The NSP in wheat, maize, and rice are mainly insoluble and have a laxative effect, while those in oats, barley, rye, and beans are mainly soluble and have a cholesterol lowering effect. In vegetables the proportions of soluble to insoluble are roughly equal but vary in fruits.

So in general we can conclude that when delivering rice bran to the feed industry:

- The higher the NDF, the better de dry matter intake.
- As ADF increases the dry matter intake will generally decrease.
- High percentages of NSP's have a negative effect on the digestion of animals.

The list of nutrition parameters as provided by the industry should be the guideline when preparing the national standards for raw and stabilized rice bran.

Required composition for food applications

Since stabilized rice bran is still not used for food applications in Suriname there are no quality references.

As a reference though, the standard for full fat stabilized bran, adopted by the USA Rice Millers Association in 1990, can be used . A definition and minimum standard specification for full-fat stabilized and parboiled rice bran for food use was presented in this standard.

Definition:

Rice bran is the brown outer layer of the brown rice kernel that is removed when milling brown rice to milled or white rice. The bran is comprised primarily of the pericarp, aleurone, and subaleurone layers of the kernel, and typically includes the embryo or germ and a small amount of the starchy endosperm.

Full-Fat Stabilized Rice Bran for Human Food shall be suitably treated after milling to deactivate the naturally occurring lipase enzymes, which, if untreated would rapidly deteriorate the oil in the bran.

To assure its purity and suitability for human consumption , Full-Fat Stabilized Rice Bran For Human Food shall met or exceed the following minimum specifications as determined by the corresponding analytical methods as specified in table 15.

Table 15. USA-Rice Milers Association standard for Full-Fat Stabilized Rice Bran For Human Food, 1990

Product	Analysis	Approved Methods AOAC	Approved Methods AAAC
Fat	Min 16%	7.056	30-25
Protein(Nx5.95)	Min 13 %	2.057	
Total dietary fiber	Min 20%	JAOAC 71:1017	
Crude fiber	Min 9%	7.061-7.065	32-10
Ash	Max 10%	14.006	08-01
Ash in parboiled rice bran	Max 15%		
Moisture	Max. 12%	14.004	44.15
FFA in crude fat extract	Max 4 %	28.029	02-01A
Silica (SiO2)	Max 0.1%	3.005	40-21
Calcium carbonate	Max 2%		
Calciumcarbonate in parboiled rice bran	Max 6%		

Source: USA Rice federation

Toxins and residues in rice bran

In the Caricom standard for rice and the rice export as in the Rice Export regulation of Suriname derived for the Caricom standard, factors are included for :

- Toxins
- Residues of pesticides
- Heavy metals

These factors should also be included into standards for raw and stabilized bran since high values of these substances in bran for application in feed or food are forbidden in international food safety regulations.

6.7. Rice value chain schedule

Currently rice millers market their rice bran through agents, to the feed industry or directly to cattle farmers to be used for animal feed for poultry, pigs and cows.

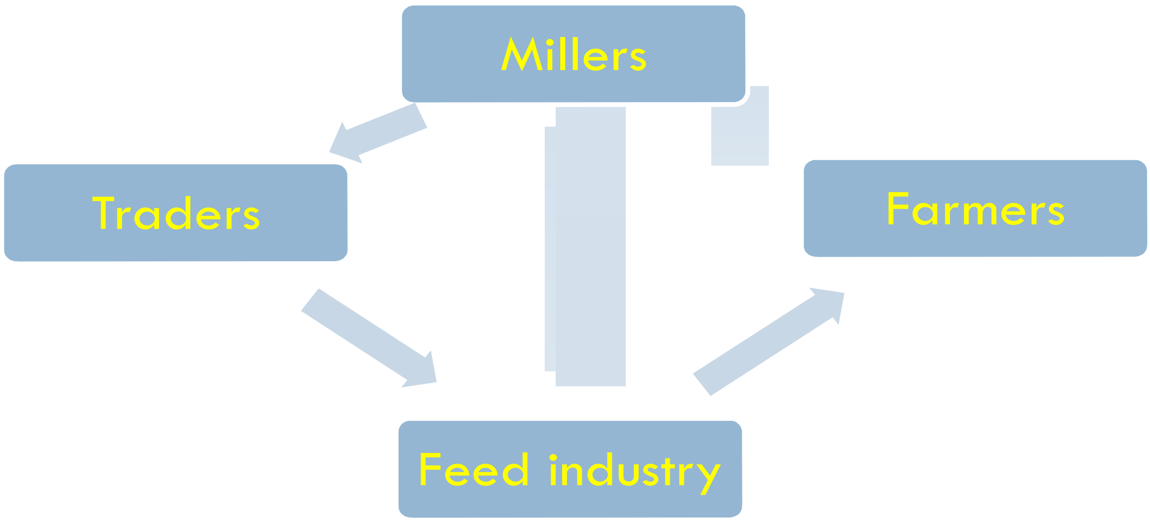


Figure 4. Current situation

When introducing stabilized rice bran into the rice value chain the value chain from milling to consumer will change from the schedule in fig. 4 to that in fig.5.

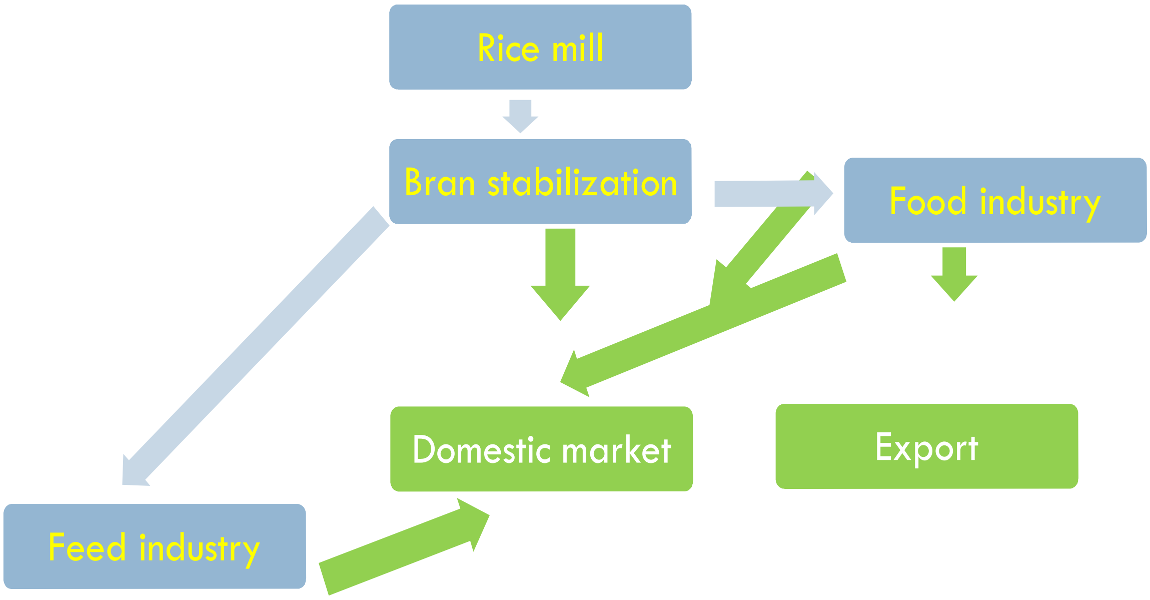


Fig 5.Value chain after stabilization of bran

The schedule in fig 5. indicates clearly that by stabilizing the bran the millers will have more marketing options and additional value is added to the stabilized bran through the food and feed industry. The domestic market in this schedule includes farmers, wholesalers and retailers. The food industry includes bakeries, diary producers, snack producers and rice bran oil plant(s).

7. OPTIONS FOR RICE BRAN STABILIZATION

7.1. CENTRALIZED OR DECENTRALIZED STABILIZATION UNITS

During the last years introduction of commercial systems in rice producing countries producing stabilized bran has increased and several rice mills in the USA, South America and Asia have installed rice bran stabilization units directly after their rice polishing section in their mils. In some countries climatic conditions are not that critical. In moderate and subtropical climates, temperatures and air humidity are much lower in some seasons . The raw bran can then be stored for a longer period without being spoiled. But in humid tropical climates like in Suriname, temperature varies between 25 and 35 ° C while most of the time the relative humidity is higher than 85 %. The bran must therefore be treated within 1 hour after milling, to prevent serious deterioration, making the bran, even after stabilization, unfit for human food and even for some specialized animal feed.

In area's where there are only very small and technologically not that advanced rice mills the small quantities bran must be collected and transported to a central bran stabilizing plant. Examples of this system are known in India. In case the mill(s) have a capacity higher than 3 tons/hr, commercial systems can be supplied that can be installed directly after the polishing section.

The advantages and disadvantages of centralized or decentralized bran stabilization for the Suriname rice milling industry are compared in the following table.

Table 16. Comparison of separate centralized unit or decentralized units for bran stabilization

	Advantages	Disadvantages
Centralized bran stabilization unit	• Centralized and well qualified management • Lower depreciation cost for the stabilizing equipment • Multiple production lines for different products are probably more feasible	• A separate business entity has to be set up leading to extra investment in facilities , overhead and operational cost • Risk of higher losses due to delay in transportation from mills to central plant • Higher operational cost due to extra handling and transport. • Mills must be willing to cooperate in a joint operation or deliver the bran at stable market prices to the central operation • If central operation is financed and operated by a third party there is a risk that millers will increase their sales prices for raw bran making the venture less feasible for the investor.
De –centralized bran stabilization units	• No extra handling cost • Unit is included in the milling operation and therefore part of the management structure of the mill • Lower investments in facilities • Owner negotiate price directly with food and feed industry • Miller will accept lower profit margin than centralized unit since it will improve the feasibility of his own mill • Creating demand for qualified workers	• Number of qualified technical and management staffing is required for the industry as a whole is higher, resulting in higher overhead cost per mill. • Higher depreciation cost for the unit • Each mill should invest in minimum laboratory equipment unless ADRON can supply analytical services. .

Of course the investment cost per installed unit of capacity(kg or ton/hr) for this type of very specialized equipment are always declining when the capacity or the utilization factor of the system increases. Depreciation cost, overhead cost and some operational cost will be higher for the smallest units. Assuming however that all systems operate at the highest possible degree of utilization, the higher the capacity, the higher the profitability.

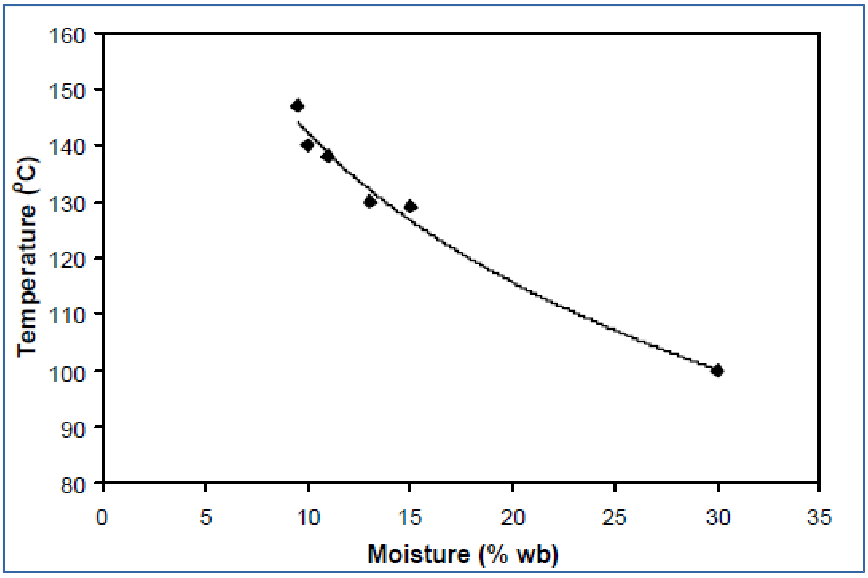
In Suriname both scenario's are possible, since most of the rice mills are located in and around Nw.Nickerie so the bran in the smaller mills can be collected and transported to a central or a larger plant. Also a combined scenario is feasible were a limited number of the larger mills install a stabilization unit and purchase raw rice bran from the smaller mills.

For Suriname the combined scenario is more realistic, since smaller mills will not have the capacity to finance and manage a stabilization plant. But since the quality of the raw bran deteriorate very fast the rice bran from the smaller mills will probably not even be suitable for high quality stabilized bran unless they can sell their cargo at better prices to the mills with stabilization equipment. Several standards could therefore be developed for feed and food use . The analysis that is done by the ADEKUS laboratory for this project can give us later this year some information on the speed at which the FFA will reach the maximum level allowed for Food application (4%) or for Feed application(12%).

7.2. Dry or wet stabilization

According to Platner(10) several studies have examined the relationship between moisture, extrusion temperature for samples with sufficient lipase inactivation. These results show , that as the processing moisture content increases the necessary temperature to denature lipase decreases significantly. This is illustrated in fig 6..

Figure 6.Temperature-Moisture relationship for sufficient Lipase inactivation



Source : Wenger, USA

Dry extrusion

One method of stabilizing the rice bran is with dry extrusion. Dry extrusion, which uses a low cost extruder and uses no added moisture, must be operated with high energy input. In this method, all the energy needed to raise the temperature of the rice bran must be obtained in the form of mechanical energy. This leads to high extruder parts cost. Dry extrusion , produces a relatively fragile product, that results in the generation of fines during oil extraction. This can limit the production of the extractor. Stabilization by dry extrusion utilizes shear, friction, and pressure to generate the heat to inactivate the lipase. Depending on the particular characteristics of the extruder and the retention time in the extruder, the temperature of the extruder must reach a minimum of 130-140 ° C for up to 3 seconds to assure inactivation of the enzyme. although this system will adequately destroy or inactivate the lipase, there is growing evidence, that these conditions may also modify some of the naturally occurring anti-oxidants, such as tocopherols and tocotrienols, which are present and desirable in bran. Since rice bran contains fairly high percentages of sucrose and other sugars, excessive shear and heat may also initiate certain Maillard reactions resulting in brownish colored bran and even scorch the bran, resulting in undesirable or bitter flavor.

The following equipment is needed in this system :

- A cylinder sifter to remove larger particles from the bran
- A single screw extruder

- Conveyor
- Belt Cooler
- Option 1 : Conditioner cylinder to be able to add water(but no steam) to the bran.
- Option 2: Optional: a APM central control panel

Extrusion cooking(wet extrusion)

This method utilizes the addition of water and steam to an extruder and pre-conditioner, and requires much lower processing temperature to inactivate the enzymes. However the moisture content of the treated bran increases to 24-28 %. This means that the bran must be dried before further processing(oil extraction) or storage for sale. After extrusion the bran will be held at 90-100 °C for 2-3 minutes. The stabilized bran produced with this method is much lighter in color and the losses of the E-vitamins and other phyto-chemicals are much lower than in dry-extrusion. The extruded bran can form shapes like flakes and pellets, although these are relatively fragile due to the composition of the rice bran.

Because of the multiple variables, the wet extrusion process is more delicate to operate.

The following equipment is needed in this system :

- A cylinder sifter to remove larger particles from the bran
- Extrusion cooker with conditioning cylinder
- Conveying system
- Dryer/cooler
- Steam boiler
- Compressor
- Water suplly
- Optional: a APM central control panel

Advised process(es) for Suriname

Option 1:Dry Extrusion with extra options

Although the dry extrusion bran may be less valuable, some millers, especially the small millers, may prefer the dry extrusion system. To be more flexible with the stabilization recipes it may be advisable to include option 1(the conditioner) in the system. This system does not need additional facilities for water and steam. A compressor may be needed to cool the retention chamber after the dry-extrusion. But since most mills will already have a compressor this may not cause extra investments.

Option 2:Extrusion cooking complete with all extra options

To have the maximum flexibility the wet extrusion system should be preferred. Investment cost will be much higher and probably more qualified operators are required, but some operational cost will be lower and the sales prices may be higher if a market is found for this product

8. UTILIZATION OF AND MARKETS FOR STABILIZED BRAN

The deterioration of the rice bran in Suriname, as already discussed in this study, is causing problems for millers, feed industry and poultry and cattle farmers since the quality is very variable, the use is limited and the supply is erratic . This results in a volatile market with currently very low prices. The increased field production and milling of white rice in the near future will only worsen the situation.

Based on our observations the demand from the Feed industry will rise since domestic high quality stabilized bran may (partly) substitute other high fat, high fiber ingredients and the production planning and recipes of the feed mills will be accomodated.

The demand from the domestic food industry must be developed by advocating the advantages of new food products with stabilized bran as a major ingredient and with health benefits to both the food industry and the consumer.

Complementary to the local market there is a potential large market for stabilized rice bran for the feed industry and food industry in the Caricom.

The promotion of stabilized bran to the industries in Suriname and Caricom should therefore concentrate at first on :

- Pet food industries
- Bakeries
- Snack food producers
- Health stores/industry
- Diary factories

By starting with one pilot plant domestic and foreign demand can be tested and developed.

At this stage it is very difficult to establish the price levels for stabilized rice bran that can be accomplished since reliable market information could not be collected. However, from different sources following prices for stabilized rice bran were indicated.

Table . 17. Indicative world market prices for stabilized rice bran

Product	Price (US $/ton)	Reference	Market	Period
Full fat stabilized rice bran meal	992	Wenger	Ex mill USA	2010
Defatted Rice bran meal	298	Wenger	Ex Mill USA	2010
Full fat stabilized rice bran -granular	991	Nutracea	List price USA	2008
Full fat stabilized rice bran –granular	1,212	Nutracea	List price USA	2008
Full fat stabilized rice bran meal for horses	2,640	Internet	List Price USA	2010
Stabilized rice	2,66/16 ounces	Internet-Now	Lowest list Price	2008

bran meal in Health stores		Rice Bran		
Stabilized rice bran	2,920	Kahlon(14)	Spot Price USA	2006
De-oiled rice bran	4,250	Kahlon(14)	USA	2006

Sources: internet, suppliers, literature

Since only a small fraction of the rice bran that is produced worldwide is stabilized and sold as health food whole sale prices varied between $ 2,640 and $ 5,250 a couple of years ago. Kahlon(14) estimated that if all the rice bran produced was stabilized prices could decrease to $ 1.00/kg.

Current prices as indicated for 2010 have already fallen below that level of $ 1,000/ton. Further decrease of the price can be expected, but prices of first quality Food grade Full Fat stabilized rice bran will probably never fall below the international prices for first quality milled rice.

So for the coming years prices for Food Grade Full Fat Stabilized Rice Bran will vary between US $ 450 and US $ 1,000.

The price for feed grade bran will be probably lower since it will be related to prices for corn, soybean cake and soybean oil. Also millers are purchasing husked and milled broken at prices about 50 % of the whole grain. Worldbank Commodity Forecast 2010-2015 expect that the price of the reference quality Thai 5% milled rice will drop from US $ 500(2010) - US $ 450(2015).

Price for Feed grade Full Fat stabilized rice bran for the feasibility calculation are estimated to vary between US $ 225 and US $ 500 . Price projections are presented in table 18.

Table 18. Stabilized bran rice projections 2010-2015 for budgetary calculations

Product	Stabilized rice bran prices (US $/ton) ex mill					
	2010	2011	2012	2013	2014	2015
Feed grade full fat stabilized bran	555	500	480	478	470	450
Food grade full fat stabilized bran	990	890	854	850	830	795

Source: Elmont, Worldbank

9. BRAN STABILIZATION SYSTEMS

The offers received from several suppliers for laboratory extruders, pilot installation and for commercial systems are summarized below. For the detailed quotation and technical data reference is made to annexes 7, 8 and 9,

9.1. SUMMARY OF SYSTEMS

Laboratory extruders

- Stand alone Brabender 19/25D single screw extruder for € 60,724,50 ex works
- Brabender single screw extruder 19/25D with accessories and options for € 96,810 ex works
- Brabender twin screw extruderTSE 20/40 with accessories and options for € 245,655 ex works

Extrusion cooker line for Pilot installation

- Kahl/Schule single screw extrusion cooker OE8, cap. 200-300 kg./hr for € 242,360 ex works

Extrusion cooker lines for Commercial installation

- Wenger Extrutech Extrusion cooker E525 with accessories , options and technical support , cap. 400-1000 kg/hr for € 793,120 (US $ 1,046,800)
- Buhler twin screw extruder, Polytwin 62, cap. 500 kg/hr for € 543,750
- Buhler twin screw extruder, Polytwin 93, cap. 1,000-1,500 kg/hr for € 660,000

Dry Extrusion Commercial alternative based on e-mail communications with Wenger

The same extrusion cooker of Wenger can be used as a dry Extrusion system without the computerized central panel.

Some items of the Wenger Extrusion cooker are exclude and some other are added.

- Wenger E525 extruder for dry extrusion, cap 400-1000 kg/hr for € (US $ 369,140)

9.2. PROPOSED LABORATORY TEST UNIT

The Brabender single screw extruder 19/25D with accessories and options for € 96,810 ex works gives the most flexibility to test dry en wet extrusion(only water added) under laboratory conditions. Options for side feeding of other products may not be required at this stage. If options are not included cost price ex works is € 65.810.

Quotations and technical data are presented in annex 7.

9.3. PROPOSED SYSTEM FOR PILOT PLANT

The Schule equipment can be used as a pilot plant since capacity is lower than other systems and the investment also. It could also be an alternative commercial unit for smaller mills. This unit can be installed in a mill with a whitening capacity of 2.5 – 3 ton cargo per hr. If water and steam are not available the unit can be operated as a dry extrusion system..

9.4. PROPOSED COMMERCIAL UNITS

The twin screw extruder systems that are offered by Buhler are not customary for bran stabilization as Buhler declared themselves in the communications with them. Wenger however seems to have much more experience with this technology and therefore the Wenger cooker system with a capacity of 400-1000 kg/hr can be installed in rice mills with a whitening capacity of 3 - 8t/hr could be ideal for some of the medium size mills. For the larges mills stabilization capacities of 1,200-1,500 kg/hr may be required, or two of the E525 models.

A cheaper alternative is the use of the E525 as a dry extrusion unit.

Fig 5. Commercial bran stabilization unit

10. FINANCIAL PLAN

Assumptions commercial plant(extrusion cooking)

The financial plan for the commercial plant in Annex 10 is based on the following assumptions:

- Investors are interested to start directly with a commercial plant.
- It will be a completely privately financed operation.
- The Extrusion cooking plant of Wenger is used as the basis for the financial plan of the commercial plant.
- Additional equipment as required is added .
- Sales prices are based on current level of US $ 990/ton.
- Raw material prices are based on average bran prices in 2010.
- The production is based on the highest capacity estimate of the supplier(1,000 kg/hr).
- Projected start of operation is January 2012.
- Standard fat analysis will be performed in own factory laboratory.
- Nutritional analysis will be performed by commercial laboratories or local institutes.
- Operation will start with one shift in year 1 and in year 2 and 3, 2nd and 3rd shift will be operational.
- Operations will be incorporated in an existing milling company.

The results in the first 3 years look very profitable when calculating with current low raw rice bran prices and high sales prices for stabilized rice bran.. If sales prices and production capacity decline or raw material prices rise with 50 %, the operation is still feasible.

The results are summarized in the following table.

Table 19. Summary of sensitivity calculations of commercial plant-extrusion cooking (net profit before taxes)

Scenario	Year 1	Year 2	Year 3
NET PROFIT/TON	497	596	628
NET PROFIT/TON –Scenario 50% lower prod capacity	66	116	133
NET PROFIT /TON–Scenario 50% lower sales prices	27	126	133
NET PROFIT /TON–Scenario 50% lower prod capacity and sales prices	=51	-1	15
NET PROFIT/TON –Scenario 50% lower sales prices and higher raw material prices	-64	140	198

Assumptions pilot plant

The financial plan for the commercial plant in Annex 11 is based on the following assumptions:

- Investors are not interested to start directly with a commercial plant.
- One miller is willing to participate in the pilot plant.
- It will be an operation funded by development funds.
- Participating millers will have take to over the plant after the trial period at a subsidized interest rate and after deduction of probable losses.
- ADRON PH-experts will assist the operation.
- The Extrusion cooking plant of Schule is used as the basis for the financial plan of the pilot plant.
- Additional equipment as required is added .
- Sales prices are based on current level of US $ 990/ton.
- Raw material prices are based on average bran prices in 2010.
- The production is based on the highest capacity estimate of the supplier(300 kg/hr).
- Estimated start of operation is January 2012.
- Standard fat analysis will be performed in ADRON laboratory.
- Nutritional analysis will be performed by commercial laboratories or local institutes.
- Operation will start with one shift in year 1 and in year 2 and 3, 2nd and 3rd shift will be operational.
- Operations will be incorporated in an existing milling company.

The results in the first 3 years look very profitable when calculating with current low raw rice bran prices and high sales prices for stabilized rice bran. If sales prices and production capacity decline , raw material prices rise as projected with 50 %, the operation is not feasible. Probably the risk is much higher here since the capacity is much lower.

The results are summarized in the following table.

Table 20. Summary of sensitivity calculations of pilot plant (net profit before taxes)

Scenario	Year 1	Year 2	Year 3
NET PROFIT/TON	257	424	475
NET PROFIT/TON –Scenario 50% lower prod capacity	-48	36	62
NET PROFIT /TON–Scenario 50% lower sales prices	-213	-47	5
NET PROFIT /TON–Scenario 50% lower prod capacity and sales prices	-165	-81	-55
NET PROFIT/TON –Scenario 50% lower sales prices and higher raw material prices	-495	-156	-59

Assumptions alternative commercial plant(dry extrusion)

The financial plan for the commercial plant in Annex 10 is based on the following assumptions:

- Investors are interested to start directly with a commercial plant.
- It will be a completely privately financed operation.
- The dry extrusion plant of Wenger is used as the basis for the financial plan of the commercial plant.
- Additional equipment as required is added .
- Sales prices are based on the estimated level for feed grade stabilized ban for 2010(US $ 555/ton).
- Raw material prices are based on average bran prices in 2010.
- The production is based on the highest capacity estimate of the supplier(1,000 kg/hr).
- Projected start of operation is January 2012.
- Standard fat analysis will be performed in own factory laboratory.
- Nutritional analysis will be performed by commercial laboratories or local institutes.
- Operation will start with one shift in year 1 and in year 2 and 3, 2nd and 3rd shift will be operational.
- Operations will be incorporated in an existing milling company.

The results in the first 3 years look very profitable when calculating with current low raw rice bran prices and high sales prices for stabilized rice bran.. If sales prices and production capacity decline or raw material prices rise with 50 %, the operation is still feasible.

The results are summarized in the following table.

Table 21. Summary of sensitivity calculations of commercial plant-dry extrusion (net profit before taxes)

Scenario	Year 1	Year 2	Year 3
NET PROFIT/TON	191	238	253
NET PROFIT/TON –Scenario 50% lower prod capacity	16	40	48
NET PROFIT /TON–Scenario 50% lower sales prices	-72	-26	-11
NET PROFIT /TON–Scenario 50% lower prod capacity and sales prices	-50	-25	-18
NET PROFIT/TON –Scenario 50% lower sales prices and higher raw material prices	-61	39	66

11. CONCLUSIONS AND RECOMMENDATIONS FOR A STRATEGY TO INTRODUCE RICE BRAN STABILIZATION IN THE SURINAME RICE INDUSTRY

11.1. CONCLUSIONS

- The desk and field research show that there is an urgent need to add value to rice byproducts to be able to maintain a sustainable rice industry in Suriname.
- Since raw bran is the product of the rice plant with the lowest value and also with the highest nutritional and therapeutic properties, adding value to this product is the most logic step to improve the profitability of the sector.
- The technical facilities of the majority of the rice mils and management are improve to a level that, with some support from relevant technical assistance they are ready to introduce bran stabilization processes.
- The technology to stabilize the raw rice bran in such way that the nutritional and therapeutical properties of freshly produced raw rice bran are maintained is available.
- The raw material is available and the will increase if production area and yields increases.
- If the bran stabilization is as profitable as projected, the demand for bran will increase and thus the export of milled rice.
- Millers have a choice between an extrusion cooking plant as used for this study or the dry extrusion plant that is much cheaper and simpler to operate. The quality of the finished product though is different from the stabilized bran produced with extrusion cooker and maybe sold at a (much) lower price.
- The international market for stabilized bran is not very transparent since regular market reports did not include these prices.
- If the introduction of rice bran stabilization is successful, not only the rice milling industry would benefit. Farmers may get better paddy prices and the government will collect more taxes. Also an increasing demand for qualified workers in the industry will benefit students of middle and higher technical education in Nickerie,

- The industry did not have the technical and commercial capacity to market their products effectively and efficiently and introduce new technology and products without outside support. There is no bundling of marketing efforts to reduce cost and increase effectiveness.
- Exporters complain that they cannot compete on international and Caricom markets since Surinamese rice is offered at too high prices, according to the traders and sales agents. Although rough rice prices in Suriname are one of the lowest in the world (Annex 3), the milling industry is able to compete since they do not operate very efficient since milling capacity in most mills is underutilized, packing systems are used inefficiently and only modernize slowly, and individual procurement of consumables, marketing , sales and exports by mills lead to high processing and marketing cost
- The demand for food grade and pet food grade bran can only be developed if stabilization test can produce stabilized rice bran in small quantities that can be used in tests in the food processing industries. They too will have to develop new products, unless the stabilized bran can be used as a substitute for other high fiber additives in existing products. Industries that could benefit from these developments are among others : bakeries, meat industry, diary industries and producers of puffed and ready to eat cereals and crackers .
- If the stabilization of rice can be introduced successfully and increase the value of this byproduct significantly , milled rice production will increase and based on the calculations in table 4, annual bran production will increase at current level of rough rice production to 22,00-23,000 tons per year and increase gradually up to 2018, if external conditions for rice production are improved , to 30,000-40,000 tons.
-

The following is recommended:

- So , although the technology is there, the sales income is difficult to project. Further market intelligence is needed.
- To develop the industry laboratory facility must be installed in Nickerie, preferably by ADRON, to be able to develop the necessary recipes on laboratory scale and perform analysis to control the raw bran and the stabilizing effect of the operation.
- Standards for raw rice bran. feed grade stabilized rice bran and food grade stabilized rice bran should be developed and introduced based on the provided information in this report, and the ongoing research on this matter in the feed industry. For the food grade bran, the USA Rice millers Standard of 2000 can be used as a reference as well as the specifications in the Caricom Rice Standards for pesticide residues, toxins, insect and microbiological infestations and heavy metals.
- Beside the required investment in the stabilizing equipment, the individual mills should invest in additional milling equipment and quality management to guarantee a standard raw material
- Since this is a new technology ADRON should continue laboratory testing, invest in bran stabilizing laboratory equipment and equipment for chemical analysis of rice and train personnel to assist during a pilot phase and to assist millers when they install such a system.
- The objective to be accomplished by the milling industry to tackle this problem should be:

- Lowering the processing and marketing cost by improved efficiency and cooperation between mills.
- Increasing the sales revenues of rice and rice by-products.
- To invest in proven technology to utilize waste and add value to byproducts .
- To cooperate with national and international rice research institute studying new technologies and participate in the operational testing and introduction of new technologies.

- The Government should commit to provide the necessary funds for preliminary research by ADRON/ADEKUS to develop and test bran stabilization installations and recipes and to perform a marketing study.
- The Government should also commit to finance additional laboratory equipment for ADRON to facilitate process control during stabilization tests and to assist the milling industry by providing quality certificates for raw bran and stabilized bran
- ADEKUS should speed up the implementation of a complete laboratory for food analysis and testing in order to assist the industry to develop products from agricultural product and byproducts such as rice and rice bran
- A PPP project steering group should be installed to monitor the project and in which the VRE, the Government and ADRON/ADEKUS will participate
- VRE should set-up a special commercial rice bran stabilizing entity where all members participate through as a shareholder to manage the company or individual millers should commit their participation in the project.

- The industry will have to develop standards for raw rice bran and stabilized bran food grade bran for the feed and food industry as well as stabilized bran and bran derivates for consumer products.

11.2. Recommendations for a strategy to introduce rice bran stabilization

The first step to be taken introduce rice bran stabilization in the Suriname is to create awareness in the rice industry, the feed industry and the food industry for the special properties and the opportunities of stabilized rice bran for use in feed and human food. But also the public must be informed .

If some millers and feed and food processors are interested, the second phase could start by performing extensive testing with a laboratory extruder by ADRON, to produce high quality bran for the feed and food industries interested to do some tests. ADEKUS-Agroprocessing could be of assistance with the application of stabilized bran in their products.

During that period discussions could start between relevant ministries(LVV, HI, PLOS) and interested rice millers how to set-up and finance a pilot plant.

But during the process described above, private investors may be interested to finance a commercial bran stabilizing plant and other products from rice bran.

By presenting this report in two mini workshops to the business society and other relevant institutes in Paramaribo and Nickerie t,e first step will be taken to create awareness for the possibilities of rice bran stabilization in Suriname and discuss and amend the recommended strategy to introduce rice bran stabilization in the rice industry in Suriname.

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ANNEXES 1-12:

Annex 1. Terms of reference

Annex 2. Logic framework

Annex 3. Producers rice prices 2005-2007

Annex 4. Protocol laboratory bran stabilization test(Dutch)

Annex 5. Examples of commercial applications of stabilized rice bran

Annex 6. SWOT-Analysis

Annex 7. Documentation and quotation of laboratory extrusion equipment

Annex 8. Documentation and quotation of commercial pilot rice bran stabilization system

Annex 9. Documentation and quotations of commercial rice bran stabilization systems

Annex 10. Financial plan commercial plant-extrusion cooking

Annex 11. Financial plan pilot plant

Annex 12. Financial plan commercial plant- dry extrusion