NARP RICE PROGRAMME

AND

THE NATURAL RESOURCCES INSTITUTE

A TECHNO –ECONOMIC STUDY TO ASCERTAIN THE NATURE AND VIABILITY OF RICE PROCESSING SYSTEMS IN NORTHERN GHANA

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ABREVIATIONS AND ACRONYMS

AR	Ashanti region
GAR	Greater Accra region
ITTU	Intermediate technology transfer unit
NR	Northern region
UE	Upper East region
UW	Upper West region

EXCHANGE RATES AND WEIGHTS AND MEASURES USED

Exchange rate (January 1998) £1: 3,600 cedis (¢)

1 bag of paddy weighs 75 - 80kg

1. INTRODUCTION

1.1 Background

This study forms part of a larger project investigating rice production in Ghana and analysing the factors responsible for the poor marketability of locally-produced rice compared with imported rice. It is funded by the Department for International Development's Post-Harvest Programme and has been conducted in collaboration between the Food Research Institute, Accra; the Savannah Research Institute, Tamale and the Natural Resources Institute.

Rice is the fourth most widely-produced cereal in Ghana after maize, sorghum and millet and contributes 10% of total cereal production. Annual rice production has increased considerably since 1990, when 81,000 tonnes of rice were produced, to 216,000 tonnes in 1996. Over 60% of the crop is grown in two northern regions – Upper East and Northern region - with 75% of production from rain-fed land. Rice is a cash crop - an estimated 80% of rice produced is sold; the remainder is consumed at household level or kept for seed. It is an important, income generating, commodity for women as they are involved throughout the production chain from planting to trading. Processing, particularly milling has been identified as a constraint to improving the quality of local rice which is considered not to compare well with imported rice (Bam *et al*, 1998). Liberalisation of trade has led to a steady increase in rice imports and currently it is estimated that close to 70% of the rice consumed is imported (SOFRECO, 1996). Rice is an important food for urban dwellers and is taking over from traditional, mainly root crop, staples. Imported rice is generally perceived to be of a higher quality; it also costs more than local rice (Day *et al* 1997; Bam *et al*, 1998). Many urban consumers are said to prefer imported rice even though it is more expensive because it looks cleaner, is more highly polished and is more prestigious to eat and to offer to visitors. However, local rice is said to taste better. People say they feel they are eating rice when they eat local rice. They also accept that the rice has to be sorted to remove the stones before cooking.

The need to make local rice more competitive is recognised, particularly in light of long term prospects of a downturn in Asian rice production and the high cost of transporting rice from the African coastal cities in-land. Most research work in the past has concentrated on the pre-harvest factors such as yield and disease resistance. With rice production now increasing each year (MOFA, 1997) there is an urgent need to know about the adequacy of processing techniques. Information is also required about the reasons for poor quality; opportunities for upgrading equipment; barriers to entry; location of mills; installed capacities and capacity utilisation.

Most of the 100 plus mills operating in the country are small de-huller mills which mill small quantities of paddy for traders on a custom basis.

1.2 Study objectives

This objective of the study is to examine the technical and economic performance of representative rice processing systems - parboiling and milling to:

(i) ascertain issues;
(ii) identify critical points for interventions to improve product quality.

1.3 Survey Design and Research Methodology

Three different sets of questionnaires were developed for this study. One was concerned with mainly socio-economic data; the second with more detailed technical information, particularly on mill capacities, capacity utilisation and milling out-turn, and the third with the parboiling process.

Interviews were conducted at 35 mills in towns in the Northern, Upper East, Upper West, Ashanti and Greater Accra regions. The towns selected included Tamale, Navrongo, Wa, Kumasi and Accra. They were chosen because of their likelihood of having a greater number of potential respondents to provide adequate information. Twenty-eight were custom steel huller mills, five were custom rubber roller mills and two were larger-scale systems using rubber roller mills. The location of the mills surveyed is shown in Table 1.

Table 1. Location of survey mills

Technology	Upper East	Upper West	Northern	Ashanti	Greater Accra	Total
Steel hullers	6	9	12	0	1	28
Small-scale rubber rollers	0	1	0	3	1	5
Large scale rubber rollers	1	0	1	0	1	3
TOTAL	7	10	12	3	3	36

1.3.1 Rice quality study

In addition to the technical details collected from the questionnaire, the following samples (approximately 1kg) were taken, whenever possible, from the mills visited.

- Paddy before milling (parboiled or raw)
- Milled rice, direct from the mill
- Milled rice, ready for the market

The moisture content of each sample was taken using a Kett Moisture Meter. This instrument measures moisture content in the range of 11.0 - 30.0%.

All the paddy samples were visually examined for contamination with stones and weed seeds and then dehusked by a double pass through a Satake (THU 34A) laboratory Rubber Roll Dehusker. The brown rice was then examined for the presence of immature (green), chalky, mouldy and red grains. The brown rice samples were test milled using a Satake (BS08A) laboratory single pass friction mill.

The degree of whiteness was set to between 'low' and 'medium' on the equipment. The yield of both brown and milled rice as well as the percentage broken grain was also determined.

In the case of milled rice samples, the following quality attributes were measured to enable the overall quality of samples to be compared with international rice quality standards:

- broken grains
- foreign matter (organic and inorganic)
- red rice
- immature grains
- chalky grain
- pecks (in parboiled rice)

Milled grains were stained with methylene blue/eosin Y stain to visually estimate the degree of milling.

1.3.2 Parboiling methodology

The parboiling process was followed closely, documented and filmed in the three northern regions for differences in technique and end quality. Samples were taken at various stages of the parboiling process:

- Paddy which has been winnowed and dried and ready to be parboiled
- Dried parboiled paddy, ready to be milled
- Milled rice, direct from the mill
- Milled rice, ready for the market

In order to obtain a direct comparison of parboiling and milling techniques, selected women from each of the three regions were asked to process sub samples of a uniform batch of paddy. These sub samples were subsequently milled in selected mills in the different regions.

All samples were subjected to laboratory analysis, as described in 1.3.1.

2. RICE PROCESSING IN GHANA

2.1 Preharvest and harvesting aspects which affect processing

In a report on the post-harvest practices of rice production in northern Ghana, produced during the same project, the following factors were identified as affecting quality (Manful and Hammond, 1998):

- Much of the rice is grown from impure seed, with high levels of varietal admixture, resulting in uneven grain maturity at harvest and variation in size and shape of the paddy grain. Admixtures therefore affect the quality of milled rice, both raw and parboiled. Some varieties have a greater husk-kernel proportion resulting in a low milling outturn.

- Many non-irrigated rice growing areas suffer from water deficits that may affect grain filling and maturation and therefore have a subsequent effect on the quality of milled rice.

- Lodging on an extensive scale can affect the quality of the milled rice, as grains that come in contact with the soil and water are prone to fungal attack and discoloration.

- Manual harvesting appears to have little effect on paddy quality. Grain harvested by combine harvester is of inferior quality with a larger proportion of broken grains and organic contamination (weed seed, chaff etc).

- In many areas, threshing is carried out by laying the panicles on dirt floors on the farms. The panicles are then beaten with sticks to remove the paddy grains and the threshed grains are swept off the ground. There is, inevitably, considerable contamination with stones and mud.

- Paddy drying is often done on clay floors as very few farmers have tarpaulins or concrete drying floors. The effect of this is more stones in the paddy after collection and bagging.

- Over-drying, either pre- or post- harvest and the consequent cracking of the grain results in a high percentage of brokens in milled rice. Good parboiling can largely overcome this problem.

- Paddy is usually traded in relatively small quantities. Price is dependant on supply of available paddy (seasonal variation), not on paddy quality.

2.2 Overview of the rice processing sector

The rice-processing sector, particularly in northern Ghana, is informal in nature. Mills are not required to be licensed. It would appear that anyone who has the money and inclination can become a rice miller. Rice processing in Ghana may be characterised into three based on the scale of operation and the investment level. (i) Household processing, (ii) Small-medium scale custom milling, and (iii) Large-scale market oriented rice processing.

It is difficult to be certain how many rice mills exist in the country, as there are no registers of mills. Also, the most widely used rice mill in northern Ghana - the Engelberg huller - is used to dehull other grains such as maize and sorghum.

2.2.1 Household processing

Rice processing for domestic consumption in rural areas is normally carried out within households as a labour-intensive, manual activity using locally-available equipment. Paddy (raw or parboiled) is put in a wooden mortar and pounded with a wooden pestle by one or more women. The processes involved in household-scale parboiling are similar to those discussed under 2.2.2 below.

The husk is removed from the pounded grain by hand winnowing, relying on wind to blow away the lighter particles as the grain is poured from one container to another or tossed in a winnowing basket. The remaining unshelled paddy is isolated by skilful use of the winnowing basket and is further pounded until all husk is removed. To remove the bran layer, the brown rice is pounded again and winnowed to remove the bran.

Rice produced by manual pounding is usually for home consumption, with small surpluses being traded mainly to neighbouring households. As such, it rarely enters the marketing chain. The process was not evaluated as part of this survey.

2.2.2 Small–medium scale rice processing

Beyond family consumption is the need to supply the market with milled rice. Rice processing in Ghana is dominated by small to medium-scale mills. Much of the milling is done on a custom basis – paddy is milled for a set price - and traders, mainly women, handle large quantities of rice. Milling is done by machines operated by diesel or electric motors. Most mills are owned, and operated, by men.

Milling efficiency (out turn) is the percentage of white rice obtained from the paddy. Factors influencing milling out turn include (i) the uniformity of the paddy, (ii) the variety of paddy shelled, (iii) the condition of the paddy, (iv) the type of machine, (v) the condition of the mill, and (vi) the skill of the mill operator (Pillaiyar, 1988).

Rice may be milled raw or parboiled. Raw milling is suitable when rice harvested at physiological maturity or at high moisture contents and gradually dried to optimum moisture levels. Paddy harvested after physiological maturity, or at low moisture contents, is unsuitable for raw milling because stress fractures in the grain result in a higher proportion of broken grain on milling. In such conditions, the grain may be parboiled to reduce breakage.

Parboiling is carried out exclusively by women who use, mainly, family labour to fetch water and firewood for the process. With increasing deforestation parboilers find it cost effective to buy the firewood instead of spending time collecting scarce firewood.

2.2.3 Types of milling machines

a. Engelberg type (steel) huller mill

The Engelberg huller consists of a hollow cylinder containing a rapidly rotating fluted roller. Axial movement of the paddy is accomplished by the action of an integral, truncated screw conveyer located at the point where paddy enters the hollow cylinder. Husking takes place as a result of the shearing action produced on the grain by the movement of the roller against a stationary blade. The combination of rapid rotation, high pressure and inter-grain contact results in the removal of both husk and bran as the paddy passes through the machine. Husk, bran and some small brokens pass through the slotted screen in the lower half of the cylinder. The milled rice is discharged at the terminal end of the chamber. The extent and efficiency of polishing is achieved by adjusting the distance between the static blade and the rotating fluted roller and by manipulating the flow of the paddy and discharge of polished rice (Grist, 1975). Throughput is usually within the range of 250 – 450 kg paddy per hour.

Paddy dehusking and polishing may also be done in two operations. In the first pass between 80 and 90% of the paddy is shelled with limited polishing (Grist, op.cit.). This is passed through the huller again to polish it. Milling rice using the huller results in low total and head rice recovery, high percentage of broken grains particularly during raw milling, mixing of husk with bran and a relatively high power consumption per unit of milling capacity. It is less suitable for raw milling but it does offer the advantage of simplicity in design, and ease of maintenance, fabrication and repair locally.

Steel hullers may be fitted with an aspirator to remove all husk and bran particles from the milled rice. However, only two of the steel huller mills surveyed in Ghana were found to be fitted with aspirators.

As bran and husk from steel hullers are usually mixed together, potential income from the sale of bran as animal feed is lost. Disposal of the waste product has both financial and environmental implications.

Of the 27 steel hullers surveyed, 15 (56%) were manufactured locally by the Intermediate Technology Transfer Units (ITTU) in the country and by some local blacksmiths. Mills initially imported from Asia and Europe served as prototypes for local production.

The first mills (in the country or examined in this survey) were installed in the 1970s. These were copied by local blacksmiths in the 1990s when 20 (73%) of the mills in this survey were fabricated.

Eighteen (67%) of the hullers were large mills, known as *Buzee* mills and seven (27%) smaller *Number 7* or *Amudu* type mills. *Buzee* mills require a 25-30 hp motor while a number 7 requires a 20 hp motor. Buzee mills are more popular in towns whereas the number 7 type is a good size for a village mill.

All small-medium scale mills in the three northern regions use steel hullers. In these regions the rice is harvested in very dry weather conditions resulting in the grains cracking in the glumes before harvesting. Parboiling is the general practice carried out in these regions to reduce breakage during milling. The relatively inexpensive steel hullers are able to mill the hardened, parboiled grains to an acceptable quality.

Due to the simplicity of their design, local blacksmiths are easily able to fabricate these mills at a lower price than imported ones. Furthermore, spare parts are more readily available and cheaper than parts for imported mills though not necessarily of better quality. However, due to an increased local demand for scrap metal, local blacksmiths have reported that it is becoming difficult to obtain raw materials of the correct quality for construction.

The average price paid for steel huller mills purchased since 1990, by the millers surveyed, was ¢190,000. The price of a new steel huller manufactured by the ITTU centre in Tamale in late December 1997 was ¢1,050,000 (about £290 at early 1998 exchange rates). This price did not include the necessary 9 hp motor, which would need to be purchased elsewhere. A second-hand 15 hp motor was said to cost around ¢180,000 and a new one about ¢220,000. A *Buzee*-type mill can be bought from a blacksmith for ¢700,000.

Some 22 (82%) steel huller mills were purchased as new and the rest as second-hand, see table 2 below. Most (88%) of the locally produced mills were newly fabricated for use. In the case of imported ones, 75% of them were purchased new. The mean operating capacity of a steel huller was 286 kg/hr and powered by an electric motor with an average of 17 horsepower.

b. Rubber roller mills

Small scale, single pass, rubber roller mills predominate in southern Ghana as they are more suitable for milling raw rice, the traditional product in these areas. Very little parboiled rice is milled in the south because the more humid climate does not cause as much cracking of grain at harvest as in the north and there is no tradition of eating parboiled rice in these regions. The shelling component of rubber roller mills consists of two closely spaced rubber rollers, rotating in opposite directions and at different speeds. A shearing action is created on paddy by contact with the rubber rollers operating with a differential displacement action, which strips off the husk from the grain.

The shelling efficiency (percentage of paddy shelled into brown rice) is about 85% and with graded paddy up to 95% (Grist, op.cit.).

After blowing off the husk, the unshelled paddy may be separated in paddy separators and recycled through the sheller. Due to the resilience of the rubber rolls, neither the bran layers of the brown rice are damaged nor do sound kernels break during dehusking. Consequently, the rubber roller sheller is considered the best among the shelling equipment for raw rice. Capacity is usually 500-kg paddy per hour.

All the six rubber rollers studied were purchased new from either Japan (83%) or Taiwan (17%) see table 2 below. Each was of 500kg/hr capacity and powered by motors ranging from 15 to 20 hp with an average of 16.2hp (Table 3). Some 60% of the mills surveyed relied solely on electric power, 40% also had diesel-operated motors to run the mills in case of electric power failure. To improve the quality of milling all the mills were equipped with some accessories. One mill had only an aspirator, five had aspirators and magnets to provide better-cleaned rice than observed with most steel hullers.

Table 2. Average capacity of mills surveyed

	Steel hullers	Rubber rollers
Proportion purchased new (%)	82	100
Capacity (kg/h)		
(i) Upper East Region	260 (14 hp motor)	-
(ii) Upper West Region	220 (13 hp motor)	-
(iii) Northern Region	380 (21 hp motor)	-
(iv) Ashanti Region	-	500 (17 hp motor)
(v) Greater Accra Region	-	500 (16 hp motor)

Note: Motor capacities are in parentheses

2.2.4 Parboiling

According to Grist (op.cit.), parboiling probably originated in India some 2,000 years ago and is now practised in many countries, and is simply a process of steeping paddy in cold water and then into hot water or in steam at low pressure.

Araullo *et al* (1976) list the objectives of parboiling as follows:

- to increase the total and head rice yield of paddy
- to prevent loss of nutrients during milling
- to salvage wet or damaged paddy
- to prepare the rice according to the requirements of consumers in certain parts of the world.

The advantages of parboiling have been summarised in an FAO (1949) report as follows.

> "Parboiling makes it possible to produce, from a given amount of paddy, more rice, with less breakage in milling; to use a lower grade of paddy to obtain rice with superior keeping qualities; and to retain more of the nutrient of the grain during milling, washing and cooking. As a consequence, the adoption of parboiling would result in a large saving of rice and, even more important, of valuable vitamins and minerals".

In northern Ghana parboiling has become a standard practice before rice is milled. Parboiling of paddy is a very important part of processing in the region's rice industry. This operation is carried out exclusively by women. The scale of operation is small - generally less than 100 kg at a time in all the three regions - and only family members are involved. Typically, the parboiling is carried out in iron pots on open fires in the compounds of their homes. Variations in technique, and subsequently the quality of the end product, exist among the women of the three different regions.

Women in the Upper East and Upper West were found to be much more aware of the importance of good quality grain and of washing the paddy before use to remove debris and immature grains. They skimmed the surface of the water to remove "floaters" (immature grains and weed seeds) and constantly removed stones and other foreign matter during drying. They also took great care to keep their fires burning fiercely, even though wood was difficult/expensive to obtain, as they believed heat intensity was crucial to good quality parboiled rice.

The impact of water quality on parboiling was not assessed during this survey; however, it was not mentioned as a problem by any of the women.

In Upper East and Upper West the women always used cement drying surfaces or rocks whereas in the Northern region the women sometimes used clay floors. The paddy was frequently turned. Drying times were reported to range from three hours to three days depending on season. However, in good drying conditions the average time was six hours. In the Upper East women tended to dry the parboiled paddy over two days, four hours on the first day and two on the second. The women in all three regions avoided drying during the heat of the day, moving the paddy to a shady area if available. It was observed that the depth of paddy was also adjusted during the drying period to prevent over-drying.

Though the moisture content of raw paddy was higher in the Upper West, the women dried the parboiled paddy to around 11% (table 9). In the Northern region, parboiled paddy had an average moisture content of 15.8%, with one sample as high as 19.9%. This obviously has serious implications for storage although most of the parboiled rice is milled and sold within a few days of processing. The women interviewed were not concerned with problems of long-term storage. The type of drying floor (clay) may be responsible for higher moister contents as drying time and frequency of turning appears to be similar in all regions.

2.2.6 Large-scale rice processing

Large-scale rice processing employs modern rice-milling installations consisting of several unit operations. These include pre-cleaning devices, shellers, separators, polishers, graders and bagging/weighing equipment. Capacity is usually in the region of 1-5 tonnes of paddy per hour. Such mills require huge investment costs. Currently, there are five such mills in Ghana, in the domain of parastatal and governmental institutions. If all of these mills were fully operational, they could account for a substantial amount of rice milled in Ghana.

The two large Satake mills studied, bought from Japan and installed in excellent housing in Tamale and Tono have a capacity of five tonnes/hour and one tonne/hour respectively (for raw rice). The mill in Tamale also has an automated parboiling facility with a capacity of four tonnes/hour.

Annual capacity of Nasia mill, Tamale:
4-5 tonnes per hour x 8 hours per day x 220 days per year = 7,040 tonnes

Annual capacity of ICOUR mill, Tono: 1 tonne per hour x 8 hours per day x 220 days per year = 1,760 tonnes

2.3 RICE PROCESSING TECHNOLOGIES SURVEYED

2.3.1 Parboiling

Paddy, 180 kg of GR18 variety grown in 1997 and harvested from a seed grower's farm, was purchased and divided into three lots for three women, one each in the Northern, Upper East and Upper West regions, to parboil. The processes followed by each woman were documented and the resultant parboiled samples milled in different mills.

The paddy had been harvested using a combine harvester and as a result, the levels of broken paddy grains were very high. While the two women from the Upper East and Upper West regions were quick to identify the sample as mechanically harvested and therefore not ideal for parboiling, this was not the case in the Northern region. The woman from the Upper East region decided that because the paddy had been combine harvested, it needed a special pre-treatment. Here, after washing and cleaning, she soaked the paddy in cold water overnight before proceeding with the usual hot soaking.

Upper East and Upper West Regions

- The paddy was washed in clean water (as much as possible women in these two regions endeavoured to obtain potable water for the washing and parboiling processes) to remove immature grains, chaff and straw. The cleaning with water also removed some stones from the paddy by gravity separation.
- The washed paddy was poured into excess **preheated** water in an iron pot on fire.
- The paddy was heated with a **fierce fire** till it reached a temperature of about **80°C**.
- The hot paddy was transferred with the hot water into clay pots, some **cold water added** to completely cover the grains and left overnight.
- The following morning, the water is drained off using local baskets. The paddy is then ready for steaming.
- A **small amount of water** is brought to boiling in the iron pot and the paddy added and steamed. The paddy may or may not be covered with jute sacks. The **fire intensity here is also very high**.
- Paddy is drained and sent almost immediately to **cement** drying floors. In the Upper East region, most women have the compounds of their homes cemented for drying paddy. However, in the Upper West region, especially in Wa, the women **carry parboiled paddy onto a communal cemented drying area**. It was realised that every woman in these two regions who produced parboiled rice for sale endeavoured to have the paddy dried on cemented floors.
- The paddy was dried between five and six hours in the hot dry season with constant turning. However, the drying period could be as long as three days in the rainy season.
- The dried paddy is then conditioned by gathering into sacks and allowed to cool before milling.

Northern Region

- **No pre-cleaning** is usually done in the Northern region. The paddy with **all the straw and other impurities** was transferred directly into an iron pot.
- Excess **cold water** was poured directly into the paddy and heated to between **70 and 75°C**.
- The paddy was transferred with the hot water into clay pot and cold water added to completely cover the grains and left overnight.
- The following morning, the water is drained off using local baskets. The paddy is then ready for steaming.
- A small amount of water is brought to boiling in the iron pot and the paddy added and steamed. The paddy may or may not be covered with jute sacks. The **fire intensity here was not that high**.
- The paddy is drained and taken almost immediately to drying floors which are **very often clay**.

- The paddy is usually dried for about 6 hours in the dry season with constant turning. However, due to the fact that the clay floors do not heat up as much as the cemented floors and the fact that relative humidity is usually higher in the Northern region than in the Upper regions, the moisture content of dried parboiled paddy was found to be higher in the Northern region than in the Upper regions.
- The dried paddy is then conditioned by gathering into sacks and allowed to cool before milling.

Flow diagram for production of parboiled rice in the three regions

Upper West	Upper East	Northern
Wash to remove chaff and stones ↓ Washed paddy poured into excess preheated water ↓ Heated over fierce fire until bubbles start to rise (approx. 80°C) ↓ Scooped into clean pot, cold water added to cover grain and left overnight ↓ Drained through locally made basket ↓ Placed Into small amount of boiling water and steamed (may be covered with jute sacking) ↓ Drained and taken to almost immediately to cement drying floor ↓ Dried for about 5 to 6 hours (dry season) with constant turning ↓ Conditioned (gathered into sacks and left to cool) before milling	Wash to remove chaff and stones ↓ Washed paddy poured into excess preheated water ↓ Heated over fierce fire until bubbles start to rise (approx. 80°C) ↓ Paddy transferred with hot water into clay pots, cold water added to cover grain and left overnight ↓ Drained through locally made basket ↓ Placed into small amount of boiling water and steamed (may be covered with jute sacking) ↓ Drained and taken to almost immediately to cement drying floor ↓ Dried for about 5 to 6 hours (dry season) with constant turning ↓ Conditioned (gathered into sacks and left to cool) before milling	Paddy is transferred into pot (no cleaning) ↓ Excess cold water is poured onto paddy and heated to between 70 and 75°C ↓ Paddy transferred with hot water into clay pots, cold water added to cover grain and left overnight ↓ Drained through locally made basket ↓ Placed into small amount of boiling water and steamed (may be covered with jute sacking) ↓ Drained and taken to almost immediately to drying floors which are very often clay ↓ Dried for about 6 hours (dry season) with constant turning ↓ Conditioned (gathered into sacks and left to cool) before milling

As can be seen from table 3 below, parboilers in the Northern region tended to be older married women with no formal education, who worked in larger groups than those in the Upper East and Upper West. Parboilers in the Upper East had the most formal education and were all over 30 years of age. In the Upper West parboiling was carried out by women of all ages, both single and married. Few had a formal education.

Table 3. Social attributes of rice parboilers interviewed

	Northern	Upper West	Upper East
Age			
<20 years		12.5%	
20-29 years	14.3%	31.3%	
30-39 years	-	18.8%	66.7%
40-49 years	28.6%	12.5%	16.6%
<50 years	57.1%	25.0%	16.7%
Marital status			
Married	100%	62.5%	100%
Single	-	25.0%	-
Divorced	-	6.3%	-
Widowed	-	6.3%	-
Education			
Islamic educ.	14.3%	18.8%	-
Non formal	85.7%	68.8%	66.7%
Primary	-	6.3%	16.7%
Secondary	-	6.3%	16.7%
Full time employees (avg Number)	4.3	1.8	2.2

Operational issues

Water was obtained mainly from hand-dug wells or bore holes in the Upper West region and the supply was considered to be very reliable. In the Upper East water was obtained from hand dug wells or pipe borne water and supplies were considered to be fairly reliable and water quality was considered to be good. Most women in this region paid someone to collect the water for them. In the Northern region, water came from pipe borne sources, dams or dug out reservoirs. The latter were not considered reliable sources of water. It was noted that water used by the parboilers in this region was often of poor quality.

When asked to identify factors that affected parboiling the main issues listed by the women included water, firewood, hot working conditions and paddy supply though there were regional differences (see table 4 below).

Table 4. Main issues affecting parboiling

	NR	UW	U E	TOTAL
Total number of respondents	**7**	**16**	**6**	**29**
Reliability/cost of water supply	6	10	4	20
Cost/availability of firewood	7	6	5	18
Heat from fire and sun	1	11	1	13
Supply of paddy	3	7	0	10
Milling charges	1	3	3	7
Distance to mill	3	0	2	5
Transport costs	1	2	0	3
Tedious work	1	1	1	3
Quality of raw paddy	0	0	3	3
Back pain from turning paddy	0	2	0	2
Low demand for product	0	0	2	2
Supply of sacks	1	1	0	2
Lack of boiling pots	1	0	0	1
Power cuts at mills	0	1	0	1
Small volume of pots	0	0	1	1
Storage facilities	0	0	1	1
Cost of raw paddy	0	0	1	1
Cash flow	1	0	0	1

The majority of women sold their rice at local markets. Only three of the 29 interviewed sold directly to traders. In the Northern region and Upper East most women were aware that their produce was eventually traded in large urban markets. Women from the Upper East acknowledged that rice was smuggled over the border to be sold in Burkina Faso.

Box 1. Case study: Ajara Abdulahi, Wa

Ajara Abdulahi is 36 years old and has had ten years of primary education. Her sole occupation is parboiling rice for sale and she does this with the full-time assistance of two of her daughters. Her main equipment is iron pots for hot soaking and steaming, earthenware pots for overnight soaking and locally-made baskets to drain the steep water from the paddy. She obtains water from a hand dug well within the compound of her house. This is very reliable and provides water all year round.

She usually purchases her paddy from the local market in Wa, buying between 300 and 400 kg paddy twice weekly. She parboils an average of 80kg paddy daily. The paddy is washed with clean water to remove floating, immature, grains and inert materials as well as stones. After cleaning the paddy she hot soaks it. The 80 kg of paddy is soaked in three batches. Water is heated in an iron pot, the paddy is added to the hot water and heated to about 80^{o}C. This may take 20-30 minutes depending on heat intensity. The paddy and hot water are transferred to earthenware pots and left overnight. She makes sure that all the grains are completely submerged in water and may add cold water to ensure that they are.

The following morning Ajara drains the paddy and adds a small quantity of boiling water to steam over intense heat. The paddy temperature may reach 90-95^{o}C. Steaming lasts for around 45 minutes. The paddy is not covered with jute sacks as she believes that fire intensity is the most important factor at this stage.

The steamed paddy is then scooped from the pot and laid out to dry on the cement floor of her compound. Drying takes 5 to 7 hours on a hot day and the paddy is frequently turned using a wooden blade. After drying Ajara and her daughters gather the paddy into a heap, allowing it to cool before bagging it. It is then ready for milling.

Her expected milling outturn is between 65 and 70 % by volume, depending on the paddy quality. She sells the parboiled rice herself for 3,000 cedis per 2.5 kg bowl. Local people and traders both purchase from her and she believes the eventual destination of some of her rice could be up to 200km away.

Her main problems are the high cost of firewood and transportation and the cost of the paddy itself. She would also be pleased to see the efficiency of the local mills improved.

Mechanised parboiling

The only mechanised parboiling plant in Ghana is located at the Nasia rice mill in Tamale. This has a capacity of 4 tonnes per hour but is rarely used due to a lack of raw paddy to process. The processing plant is fully automated consisting of several unit operations, detailed below:

Precleaner to remove large debris

↓

Silo storage until required

↓

Precleaner to remove weed seed and broken grains

↓

Satake grader to remove immature/oversized grains
(up to 10% rejected)

↓

Destoner

↓

Aspirator to remove fine debris

↓

Soaking tanks
($70^{o}C$ for 3-4 hours)

↓

Net conveyor belt (drainage occurs)

↓

Pressurised vessel
Paddy is passed through on a moving belt. Resistance time 60 seconds, pressure 1kg /cm2. Steam injected from top and bottom of vessel

↓

Net conveyor belt (drainage occurs)

↓

Rotary drier (3% moisture removed)

↓

Main batch driers ($80^{o}C$, 3-4 hours to 18% moisture)

↓

Tempering bins (4 hours 55 ^{o}C)

↓

Main batch drier (achieve 2% moisture loss)

↓

Tempering bin (4 hours)↓

↓

Drying/tempering repeated until paddy has moisture content of 13-14%

↓

Airtight temperature controlled storage tank for up to 2 weeks

Economics of parboiling

Data on the economics of parboiling is extracted from Langyintuo's (1996) study of rice marketing in northern Ghana. Table 5 below indicates the impact of parboiling on returns of rice traders in Northern and Upper West regions. In the northern region the traders hail from Tolon about 25 km away from Tamale, buy paddy from Gbirimani, 10 km away, parboil and mill rice in Tolon for sale to wholesalers in Tali market. In the the Upper

West region, the urban traders buy paddy from the hinterland, about 20 km on average, parboil, mill and sell the milled rice in the Wa market.

Table 5. Costs and returns in local rice trade in northern Ghana (¢/bag)

Variable	Region	
	Northern	Upper West
Farm gate price (80 kg paddy rice)	34,000.00	32,000.00
Transport cost from farm village to store[1]	500.00	1,100.00
Cost of processing[2]	4,500.00	3,360.00
Transport cost from mill to market	1,000.00	500.00
Marketing costs[3]	350.00	400.00
Selling price of rice by assembler (50 kg milled rice)[4]	32,000.00	50,000.00
Margin to assembler (for 1 bag of paddy rice)	-2,000.00	18,000.00

Source: Langyintuo, 1996

Notes:

1 Includes loading and offloading charges.

2 Includes cost of firewood and water for parboiling, milling and winnowing charges.

3 Urban/town council charges and market tolls.

4 Conversion factor from paddy to milled rice is 62.5%.

Transforming paddy to milled rice cost traders over ¢5,000 per bag of which the cost of processing (including parboiling) constitutes 82% and 62%, respectively in the northern region and Upper West region. About 65% of the cost of processing may be attributed to parboiling and the rest to milling and winnowing charges. Traders in the northern region are making losses but are unaware of that because they do not value family labour, which is employed in processing. Firewood harvested from the woods, water fetched from the dam and winnowing are all by family labour. Added to the relatively low price for Tamale rice, due to its poor quality, traders tend to lose. In contrast, their counterparts in the Upper West make a good profit stemming from the relatively high price they receive from their produce.

2.3.2 MILLING

Ownership of mills

With only one exception, the mills surveyed were all owned by men with an average age of 44 years. Of the 27 steel hullers and rubber rollers surveyed, 84% were singly owned and the remaining 16% jointly owned by two to three individuals. These were purchased locally from traders (97%) between mid 1976 and 1997 but majority was bought within the last decade. Over 60% of all the mills were procured between 1990 and 1997. Sixty percent of the mill owners indicated their willingness to upgrade their ageing mills.

The objective of 82% of owners for operating the mills was profit and hence their willingness to invest their own capital. Some 88% of the mill owners surveyed indicated they had invested equity capital in their businesses. Bank loans accounted for 6% of investment capital source.

Condition of mill housing

Paddy sent to the mill for milling may require further drying and storage and milled rice may also require storing. It was considered important to examine the nature of housing for the mills. Premises were assessed according to the following categories:

- **Good**

A properly roofed building
Adequate storage space
Cement drying floor

- **Moderate**

A good roof
Limited storage space
Non-cemented drying floor

- **Basic**

Poor roof
Limited or no storage space
Limited or no drying floor.

The study revealed that only three (12%) of the steel huller mills were installed in good quality premises (see table 6 below). Nine (33%) were in moderate housing while the rest were in basic premises. Storage facilities were sometimes offered to traders free of charge until the rice is sold.

Sixty percent of the rubber roll mills were installed in very good housing with drying yards and storage places for paddy rice with the remaining 40% in relatively moderate housing. As in the case of steel huller mills, storage space and drying floors are offered free of charge to traders.

Table 6. Condition of milling premises (% of mills surveyed)

	Steel hullers	Rubber roll mills
Good	12	60
Moderate	33	40
Basic	55	0

Installed capacity of mills surveyed

In the case of the steel huller mills installed capacities varied from 220 kg/hr in the Upper West Region to 380 kg/hr in the Northern Region (Table 2). In the case of the rubber rollers, installed capacities of 500 kg/hr were observed in both Ashanti and Greater Accra regions.

Forty-one percent of owners were found to operate their mills on 15 HP motors appropriate for the capacity of mills installed while 9% operated on 30 HP motors, far above that recommended.

In Tamale in particular millers use over sized motors leading to high electricity charges. This practice could be blamed on ignorance although some use of such motors as a sign of wealth. Some education by staff of the Volta River Authority on judicial use of electric power has resulted in the purchase and installation of capacitors to step down power consumption to the optimum.

In the case of the large mills visited, two had an operational capacity of one tonne per hour whilst the third could process up to 5 tonnes per hour for raw rice and 4 tonnes per hour for parboiled rice. This is believed to be the only industrial-scale parboiling plant in the country. Production figures, given below, for two of these mills indicate that they are operating far below capacity:

Throughput of Nasia mill, Tamale (Estimated annual capacity, based on single shift, = 7,000t)
1994 800 tonnes
1995 200 tonnes
1996 200 tonnes
1997 nil (January to November)

Throughput of ICOUR mill, Tono (Estimated annual capacity, based on single shift = 1,800t)
1994 (wet season) 90 tonnes
1994-5 (dry season) 183 tonnes
1995 (wet season) 90 tonnes
1995-6 (dry season) 200 tonnes
1997 (wet season) 10 tonnes (incomplete figures for the season)

None of the small-medium scale millers keep records of throughput. Operational capacity is, therefore, difficult to estimate as any data relies on the owners/operators perception or memory of how often the mill is operated.

In northern Ghana where the steel hullers abound, traders mill the quantity of rice they intend to sell in the market on designated market days. Therefore, milling is mostly done on market days although some paddy may be milled on other days. It was reported that, on average, mills are operated four days a week during the busy milling months from December to April/May. During this period an average of 27 bags paddy are milled per day.

As discussed previously, rubber roller mills are predominant in southern Ghana. As these are operated in towns and cities, the sale of rice is independent of market days. Consequently, rice is milled when traders feel satisfied with the ruling price of rice.

On average, mills work for six days a week between December and May. During this time, they mill an average of 38 bags (3.4 tonnes) of paddy a day.

Compared with the installed capacities of mills, most of them were operating below full capacity even during peak periods of operation. Mills in Upper West, Northern and Greater Accra claimed to be operating above 50% capacity while those in the Upper East and Ashanti regions operated below 50% capacity (see Table 7 below).

Table 7. Operating capacities of the mills during six months of peak activity (December to May)

Region	Milling days per week	No of bags milled/day	Operating capacity (kg/hr)	Capacity utilisation (%)
Upper East	3 (1)	16 (13)	71.90 (52.14)	28
Upper West	5 (1)	24 (8)	182.86 (82.42)	83
Northern	4 (0)	41 (18)	235.71 (100.96)	62
Ashanti	6 (0)	26 (7)	225.71 (60.81)	45
Greater Accra	6 (1)	50 (20)	385.71 (122)	77

Note: Standard deviations are given in parentheses

The main reasons given for low capacity utilisation of the mills were frequent interruptions from broken parts and inadequate quantities of paddy resulting from poor supply and/or traders' unwillingness to mill their rice. This attitude greatly affects the operations of the mills. It was also indicated that unless the traders are satisfied with the ruling market price rice, they are not prepared to mill.

Background of staff employed and working conditions

Table 8. Background of mill staff

	Northern region	Upper West	Upper East	Ashanti
Age of operator				
<20		28.6		
20-29	26.8	28.6	70.0	20.0
30-39	42.8	14.3	10.0	20.0
40-49	14.3	28.6	20.0	60.0
>50	14.3			
Marital status				
Married	100	43	80	100
Educational background				
Islamic school	42.8			
Non formal	28.6	28.6	20	
Primary		71.4	50	20
Secondary	14.3		20	40
Tertiary	14.3		10	20

Knowledge of how to operate rice mills was reported to be to be through on-the-job training. The majority (97%) of operators had been attached to other mills to learn how to operate a mill before engagement. The staff considered that such training gave them the culture of regular servicing thereby ensuring good working order of the mills.

However, in one of the large-scale mills the manager reported that, when the mill was installed and commissioned, he was given only rudimentary training and had to rely on the manuals provided to adjust the mill. He felt that this training was inadequate and that the mill could operate more efficiently if he had a better understanding of the process.

None of the small-medium scale mills had any guards over moving parts (such as belt drives). Conditions inside the mill were extremely noisy and dusty and, in many cases, cramped. In only one instance was it observed that the mill operators had been provided with dust masks.

Servicing and maintenance

Many mills (91%) were reported to have been in good working order since their installation. Over 50% reported that their mills had had to undergo some massive replacement of parts. Few records are kept regarding servicing and replacement of damaged parts.

Frequency and cost of replacing mill components were the most frequently cited problems faced by small to medium scale millers. Problems with power supply and supply of paddy, particularly in the Upper East, were also mentioned (Table 9).

Table 9. Reported problems faced by mills

	Northern region	Upper West	Upper East	Ashanti
Number of mills	6	7	10	5
Problem cited:				
Sieves	4	5	7	4
Bearings	4	5	6	1
Shaft	4	4	8	3
Blade	2	3	2	-
Paddy supply	-	2	-	-
Power cuts	-	2	3	2
Belt	-	-	1	-
Aspirator	-	-	1	-
Cost of power	-	-	1	-
Cost of finance	-	-	-	1
Transport costs	-	-	-	1
Porter charges	-	-	-	1
Rubber rolls	n/a	N/a	n/a	4
Market demand	-	-	-	1

In the Northern region spares were reported to be easy to find with several stockists /local craftsmen in Tamale. In the Upper West four of the millers said spares were hard to obtain as they had to travel to Kumasi or Accra to purchase them. In the Upper East six of the millers reported that they had to travel to Kumasi to find spare parts. However, two millers stated that spares were easy to obtain from the regional capital, Bolgatanga.

Milling charges

Milling charges were reported to be fixed by millers' associations to which 80% of millers surveyed belonged. However, it is believed that, in the three northern regions these associations are, in fact, maize millers associations and that there are no associations dedicated to the interests of rice millers. At the time of the survey, charges in the Northern region and Upper West ranged from 1,000-2,000 cedis per bag with an average charge of 1,617 cedis and 1,444 cedis respectively. In the Upper East the range and average charges were 1,000-1,500 and 1,400 cedis for parboiled rice. Higher charges of 2,000-3,000 cedis per bag were reported for raw rice.

In Ashanti the millers surveyed charged by quantity of milled grains obtained, not by paddy weight. At the time of the survey, the price charged was set at 2,000 cedis per 32.5 kg of milled rice.

Parboiled rice dominates the rice milled by steel hullers. About 50% of the steel huller mills surveyed reported that they do carry out some raw rice milling, though quantities milled are very small. Rubber roller mills, on the other hand, predominantly mill raw rice. Seventeen percent of them reported that they do mill small quantities of parboiled rice. Ninety-five percent of the millers who mill both types of rice argued that care is required in raw rice milling to reduce broken grains.

By-products

Steel huller mills do not effectively separate the bran from the husk. As a result, the bran or husk is either thrown away or burnt. In one case it was reported to be used as manure. In the Northern Region and Upper East mills which did separate the two fractions sold bran to poultry farmers for between ¢400 and ¢2000 per bag. In the Upper West the bran was usually given away. In Ashanti region rubber roll mills produce two distinct by-products: bran and husk. Bran is sold to poultry farmers at an average cost of a 50-kg bag of ¢1,800. Husk was taken away and burnt; the cost of disposal was reported to be between ¢20,000 and ¢100,000 a year.

3. TECHNICAL ANALYSIS

3.1 Parboiling

3.1.1 Quality of raw paddy

Sampling was carried out in the period immediately after harvest. The moisture content of the samples from the Upper West therefore gives cause for concern. The incidence of mould damaged grain was found to be highest in this region, with one sample containing 5.27% mould damaged grain. With prolonged storage of paddy, at these moisture contents, it is likely that the grain will deteriorate further.

Weed seeds were not a problem in traditionally harvested samples. The proportions of red rice and immature grains are indicators that a sample is of mixed varieties. This might be expected to cause problems when milling, affecting the of degree of milling, % brokens and yield of milled rice.

Stones were found in all but one laboratory sample (100g). Since the incidence of even a single stone in a portion of cooked rice may adversely affect consumer acceptance of a product, this is clearly a problem needs to be addressed.

Combine harvested paddy was found to have a high proportion of broken grain (up to 9.6%), and in some cases, weed seeds (up to 14.4%).

Table 10. Quality of raw paddy used by parboilers

	Moisture content (%)	Stones (%)	Weed seeds (%)	Red rice (%)	Immature grains (%)	Mould-damaged grain (%)	Broken paddy (%)
Upper East (n=6)	<11 (<11-12.5)	0.25 (0.03-0.66)	0.03 (0-0.12)	3.80 (0.69-9.19)	4.28 (2.14-8.06)	1.29 (0.86-2.3)	0
Upper West (n=6)	14.95 (11.3-21.4)	0.21 (0-0.97)	0.01 (0-0.03)	7.74 (1.79-16.84)	6.64 (0.13-13.75)	2.50 (0.9-5.27)	0
Northern (n=1)	<11	0.23	0.50	1.79	0.13	2.07	0
Combine harvested sample	11.4 (<11-12.2)	0.4 (0.0-0.9)	3.83 (0.0-14.45)	3.25 (0.0-8.22)	0.11 (0.0-0.25)	2.3 (0.91-3.86)	7.4 (3.2-9.6)

Average and (range)

3.1.2 Impact of parboiling techniques on quality

The variations in technique between regions have been discussed in section 2.3.1.

In the Upper East and Upper West the incidence of stones in the paddy was considerably reduced presumably due to the women's diligence during drying. The presence of stones in dried paddy was higher in the Northern region. This could be attributed to either lack of sorting during drying or due to the nature of the drying floor.

A large reduction in the quantity of immature grains was found in paddy after parboiling compared to raw paddy in the Upper East and Upper West, indicative of the careful washing regimes observed in these areas. With only one sample of raw paddy taken in the Northern region it is not possible to comment on the removal of these grains in this area.

Table 11. Quality of parboiled paddy

	% Moisture content	**stones**	**weed seeds**	**red rice**	**immature grains**	**mould damaged grain**	**Broken paddy**
Upper East (n=13)	12.6 (<11-14.7)	0.16 (0-0.41)	0	1.86 (0-10.94)	0.26 (0-0.67))	1.20 (0.1-2.15)	0
Upper West (n=5)	<11 (11-11.3)	0.11 (0-0.45)	0.01 (0-0.07)	3.39 (2.65-5)	0.49 (0-1.84)	2.53 (0..83-4.71)	0
Northern (n=5)	15.8 (13.2-19.9)	0.26 (0.17-0.37)	0.07 (0.1-1.7)	9.7 (0.94-17.46)	0.49 (0.27-0.7)	2.22 (0.54-4.14)	0
Combine harvested sample	13.0 (<11-19.9)	0.3 (0.0-0.8)	0.2 (0.0-0.5)	3.4 (0.0-8.5)	0.1 (0.0-0.25)	2.3 (0.9-4.0)	6.8 (2.0-8.6)

Average and (range)

Colour of milled rice

The colour of parboiled milled rice samples was measured using a Minolta colour meter using L*a*b* colour space in which L* represents lightness (light =100, dark =0), a* is the red/green coordinate (red hues being represented by positive values and green by negative values) and b* is the yellow/blue cordinate (yellow hues being represented by positive values and blue by negative values)

The results, shown in Table 12, show that parboiled rice produced in the Northern region is considerably darker than the parboiled rice produced in the Upper East and Upper West. Indeed the lightness of the parboiled rice produced in these two regions is comparable with that of the raw rice.

As might be expected the parboiled rice produced in the Upper East and Upper West was more yellow than the raw rice, with the rice from the Upper East being the paler yellow of the two. The very low b* value recorded on rice from the Northern region is probably due to a masking of the yellow hues by the overall darkness of the kernels. This may be indicative of both poor parboiling and milling practices.

The a* values for all samples are low, being in the achromatic region of the coordinate and thus are not indicative of colour.variations.

Table 12. Colour measurements of milled rice

	L*	a*	b*
Large scale mills (raw)	47.27 (0.57)	11.80 (0.96)	12.38 (0.58)
Kumasi rubber roll mills (raw)	48.07 (0.13)	11.97 (0.58)	12.68 (0.81)
Northern region (parboiled)	30.88 (3.96)	9.92 (0.91)	11.25 (2.03)
Upper West (parboiled)	47.11 (1.13)	9.27 (0.36)	17.79 (0.97)
Upper East (parboiled)	43.61 (2.61)	10.00 (0.21)	15.71 (1.14)

3.2 Milling

3.2.1 Condition of milling equipment

In general, the overall quality of the steel huller mills was poor. Shafts were battered and had been welded numerous times to prolong their life. Sometimes entire shafts had been manufactured locally using a steel cylinder with a car spring welded on to form the screw conveyor and metal rods to form the ribs. Blades were pitted and broken. Screens were invariably broken and patched. Many millers reported that a screen might only last a few days due to stones in the paddy.

The situation with rubber roll mills was similar. Rubber rolls were worn, in one case right down to the metal. Screens were reported to last only one day before they were broken by stones. They were frequently observed to be patched and welded to prolong their life. Many millers used screens imported from Taiwan or locally fabricated screens to save money though they lasted less time than the Japanese screens. Some of the larger millers in Kumasi arranged import of their own spare parts. There were however numerous retail outlets in the town which supplied these parts. One retailer stated that he places orders annually for 3-4000 pairs of screens and 1000 pairs of rubber rolls. Some retailers had Taiwanese mills in stock.

3.2.2 Main factors affecting rice mill operations

The operations of the mills are associated with some problems arising from mainly difficulties in mills operations. Problems frequently cited by mill operators include damage caused to the sieves, shaft and casing. Damage to sieves was reported by all millers interviewed in the Ashanti and Greater Accra regions, where mainly rubber rollers are used. Shaft damage was reported only in the Northern region. The damage caused to mills was attributed to the presence of foreign particles such as stones and metals. Some rubber roller mills are fitted with magnets to attract metal pieces, their chances of causing damage to mills was minimal. Mills located in northern Ghana suffered equally from metals as well as from stones. Table 13 indicates metals as the major source of damage to the mills. Stones appear to be the cause of damage to sieves in all locations.

The main items requiring frequent replacement include bearings, belts, shaft and sieves. Rubber roller mills also have to replace the rollers while the hammer mills replace the blades. The frequency of sieve replacement, the most vulnerable part, varies from one day to about two months depending on the presence of foreign particles in the rice.
The rate of damage to sieves is greatly reduced when metals in the rice are removed by magnets as is the case in some rubber roller mills. Another factor determining the longevity of sieves is whether they are locally fabricated or imported, as imported parts tend to last longer than locally fabricated ones.

Table 13. Major types of damage caused by foreign particles in paddy
(Percentage occurrence)

	UER		UWR		NR		ASHR		GAR	
	Metal	Stones	Metal	Stones	Metal	Stones	Metal	Stones	Metal	Stones
Sieve damage	20	80	0	100	50	50	33	67	0	100
Shaft damage	0	0	0	0	50	50	0	0	0	0
General damage	100	0	75	25	67	33	0	0	0	0
Shaft casing	0	0	0	0	0	0	100	0	0	0

In ranking the problems of operating a mill, steel hullers ranked damage to shaft as their number one problem. In second place was damage to bearings and sieves.

For rubber rollers, the high cost of spare parts in general and damage to sieves were ranked highly. In second place was damage to rollers by stones.

The large-scale mills were found to be well maintained with adequate stocks of spare parts which were supplied when the mill was installed, and have lasted longer than anticipated due to under utilisation. The managers did express concern about funding the cost of spare parts in the future, when current stocks are depleted.

Box 2. Interview with Hadia Fadziya Issahak, Kumasi

Hadia Fadziya Issahak runs six Satake rubber roll mills, all powered by electricity although he does have one diesel engine which he uses when necessary.

His mill sieves only last one day before becoming perforated but are patched to make them last around 2 weeks. Each pair of sieves costs 60,000 cedis. The rubber rollers cost 120,000 cedis each and need replacing every 2 weeks. Conveyance worms cost 150,000. He order his spare parts from Jos Boateng in Accra. Delivery takes about 4 months from date of order. He usually order 100 pairs of screens and 100 rollers at a time. He would prefer to buy genuine Satake parts for their machines but as these are not usually available he uses Taiwanese parts which are cheaper but of inferior quality.

His mills are currently around 8 years old. He may consider replacing them in 4-5 years time. Satake machines from Japan are not now available. Chinese imports are thought to cost around 8 million cedis but the body and parts are not considered to be as good quality as Satake but are considered to mill equally effectively.

3.2.3 Milling practices

Northern Ghana

Mechanised rice milling in northern Ghana is almost entirely done by steel huller mills. The notable exceptions being the large rubber roll mills of Nasia Rice Co. Ltd in Tamale and ICOUR at Tono. The steel hullers are entirely custom mills. Although it is relatively easy to find out the year of installation of the mills, in most cases, this does not reflect the real ages of the mills as most of the mills are now with their second or third owners.

With the extension of hydro electricity to the northern sector, most of the mills, with the exception of a few in the Northern region, have converted from the use of diesel engines to electric motors.

Upper-East

In this region, two of the mills surveyed were fitted with aspirators. These ensure that the milled rice is relatively free of husk and bran. The women who bring the rice for milling therefore did not need to winnow the rice before sending it to the market.

A few new mills were also found in this region and these produced relatively good quality milled rice. It is worth noting that in most of the mills without aspirators, some form of winnowing was needed after milling before the rice was sold.

The average amount of bran retained on milled rice samples from this region was found to be 18.6%.

Upper-West

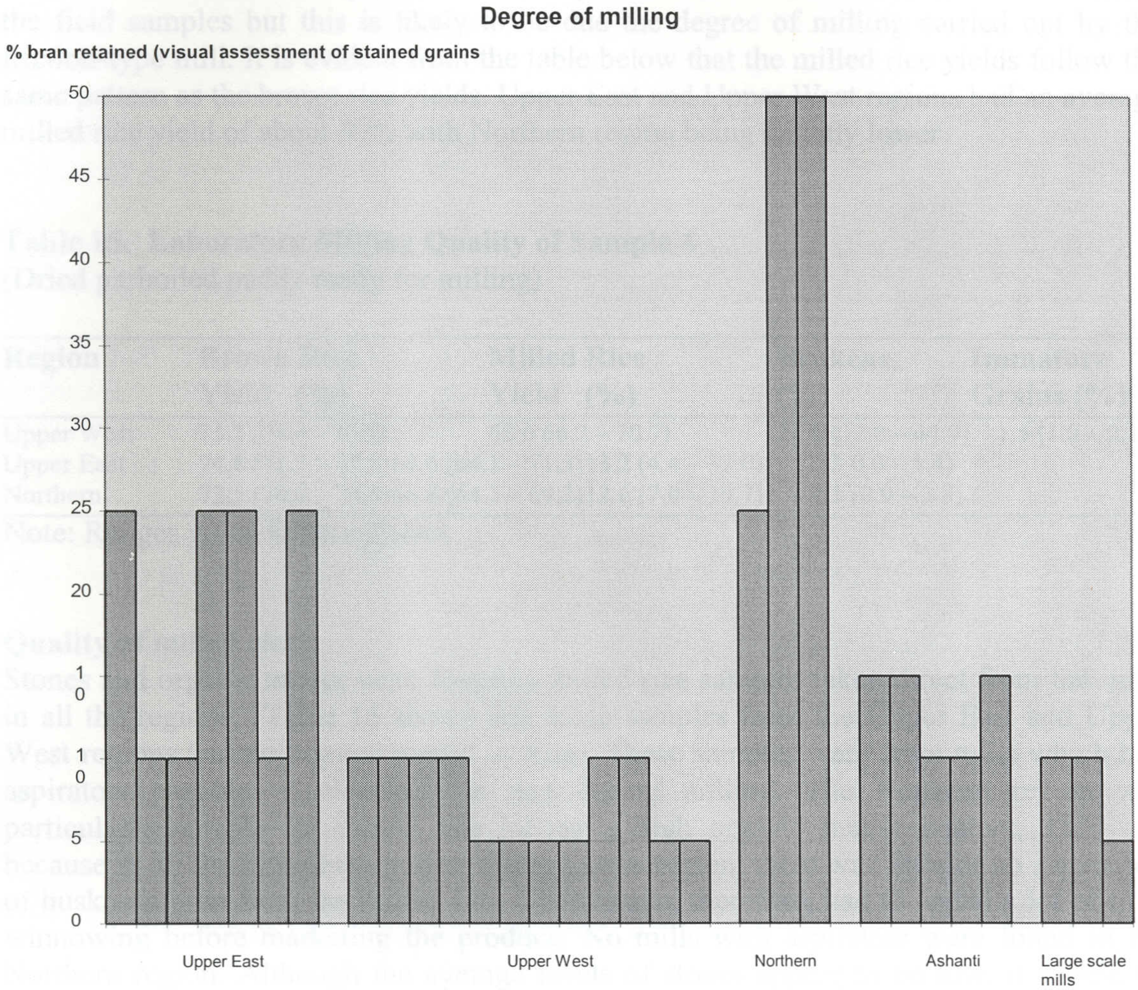
Rice mill operation in this region differs slightly from that of the Upper East region. Here, the paddy was passed through the huller twice. During the first pass, the milled rice comes out with a lot of bran and husk mixed with it. However, during the second pass almost all the husk and bran are removed and the grains are further polished. Subsequently, the degree of milling of parboiled rice in this region is higher than the Upper East region. Rice from this region almost a brighter appearance and the women did not need to further winnow the rice before sale (refer to table on milled rice quality). The amount of bran retained on milled rice samples from this region was found to be between 5 and 10% averaging 7.9%.

Northern region

Rice milled in this region was found to be of the lowest quality. The reasons for this could be two-fold. First, the process of parboiling itself was poor in this region and the mills were found to be in a greater state of disrepair. Second, the rice was not milled twice as in the Upper West and subsequently all the husk and bran came out with the milled rice. The women have to spend long times winnowing before sending the rice to the market. During this extended winnowing, some rice was also lost to the wind. As a result of all the husk and bran being retained in the casing of the mill, friction between the rice grain was reduced and the degree of milling was consequently low. The amount of bran retained on milled rice samples from this region was found to be very high, averaging 41.7%.

All of the samples obtained from mills in the Upper East and some from the Upper West were found to be as well milled as those from the commercial mills, even though produced on sophisticated large scale mills. In some cases, the degree of milling was superior to that obtained from the small-scale rubber roll mills. It should, however be noted that all rubber roll milled samples were raw rice whereas those from the Northern regions were parboiled.

Figure 1. Visual estimation of percentage bran retained after milling



Test milling of a standard sample of parboiled rice in four commercial mills in both Upper West and Northern regions showed little difference between the two regions (see table 14 below).

Table 14. Test milling of standard samples of raw and parboiled rice(steel huller mills)

Region	Type of rice	Yield (%)
UW mill 1	Parboiled	73
	Raw	59
UW mill 2	Parboiled	73
	Raw	64
UW mill 3	Parboiled	71
	Raw	66
UW mill 4	Parboiled	69
	Raw	53
NR mill 1	Parboiled	73
	Raw	
NR mill 2	Parboiled	78
NR mill 3	Parboiled	70
NR mill 4	Parboiled	74

Laboratory milling of parboiled rice samples (Table 15) confirmed little variation in yield between the different samples. Milled rice yields were lower than those observed from the field samples but this is likely to be due the degree of milling carried out by the friction-type mill. It is evident from the table below that the milled rice yields follow the same pattern as the brown rice yields. Upper East and Upper West regions had an average milled rice yield of about 69% with Northern region being slightly lower.

Table 15. Laboratory Milling Quality of Sample 4
(Dried parboiled paddy ready for milling)

Region	Brown Rice Yield (%)	Milled Rice Yield (%)	Brokens (%)	Immature Grains (%)
Upper West	75.3 (74.4 - 76.5)	68.6 66.7 – 70.7)	26.0 (12.0 – 44.9)	1.5 (1.0 – 2.1)
Upper East	74.8 (71.7 – 77.5)	68.6 (64.1 – 71.3)	13.2 (4.4 – 37.0)	0.3 0.0 – 1.4)
Northern	72.5 (70.0 – 74.6)	66.8 (64.1 – 69.2)	12.6 (7.0 – 19.7)	2.1 (0.9 – 3.3)

Note: Ranges given in parentheses

Quality of milled rice

Stones and organic matter were found in milled rice samples taken direct from the mills in all the regions. Table 16 shows that some samples from the Upper East and Upper West regions had no organic matter in them. These samples were from mills which had aspirators capable of cleaning the rice during milling. The Northern region was particularly notable for milled rice having a high organic matter content. This was because in all the Engelberg hullers found in this region, there was little or no separation of husk and bran from the milled rice. The women, therefore, had to spend a lot of time winnowing before marketing the produce. No mills with aspirators were found in the Northern region. Although the average levels of stones appear to be low, it should be noted that these levels were found in laboratory samples of 100g. The presence of a single stone in a portion of cooked rice would almost certainly render it unacceptable to the consumer. Grading is carried out only by larger mills.

Table 16. **Stones and Organic Matter in rice direct from mill**

Region	Stones (%)	Organic Matter (%)
Upper West	0.3 (0.1 – 0.6)	5.5 (0.0 – 16.0)
Upper East	0.4 (0.0 – 1.1)	3.8 (0.0 – 13.1)
Northern	0.2 (0.1 – 0.4)	13.2 (11.7 – 15.8)

Note: Ranges given in parentheses

Table 17 shows the physical quality of milled rice ready for market from the Upper East, Upper West, Northern, Ashanti and Greater Accra regions. The levels of brokens in raw rice were very high in every region, averaging over 20%. As might be expected, parboiling was shown to reduce the percentage of broken grain.
Most of the samples from the northern regions contained some stones . The samples from the Greater Accra region had no stones with those from Ashanti having relatively low levels of stones (average, 0.05%).

Few weed seeds were found. The levels of other organic matter were also very low indicating that the separation of bran by winnowing is efficient.

Rice milled in the Ashanti region had high levels of red rice with some samples being exclusively red. Red rice is grown for specific markets, it is however clear that agricultural and harvesting practices result in a small proportion of red rice contaminating much of the rice grown and marketed in Ghana.

The incidence of mouldy grains was found to be higher in the three northern regions, possibly as a result of parboiling and storage practices in those regions.

Rice from the Upper East and Upper West had low levels of white centres, ungelatinised starch, (0-2.2 -0-6.2% respectively) indicating that the parboiling techniques are efficient.

When compared with the International Standard for Rice Specification (ISO 7301), summarised in table 18, some of the samples examined would fail to meet the tolerances for inorganic matter (stones), damaged kernels (mouldy) and red rice. The level of broken grain is not stipulated under the current ISO standard but is usually specified in purchasing agreements.

Table 17. Physical quality of milled rice, ready for market

Region	Brokens (%)	Stones (%)	Weed seeds (%)	Other organic matter (%)	Red rice (%)	Mouldy grains (%)
Upper West						
Raw	57.4 (51.0-63.8)	0.4 (0.3-0.5)	0	0	3.6 (1.0-6.2)	0.8 (0.3-1.4)
Parboiled	28.3 (14.4-51.0)	0.1 (0.0-0.4)	0	0	1.5 (0.0-14.6)	0.9 (0.4-2.5)
Upper East						
Raw	71.1 (21.5-96.8)	0.01 (0.0-0.04)	0.04 (0.0-0.1)	0.01 (0.0-0.1)	1.1 (0.2-2.0)	0.9 (0.3-2.6)
Parboiled	20.8 (5.3-32.9)	0.2 (0.0-1.3)	0.01 (0.0-0.1)	0.01 (0.0-0.3)	1.4 (0.1-7.9)	2.0 (0.3-4.7)
Northern						
Parboiled	23.8 (6.8-39.4)	0.3 (0.0-0.9)	0.1 (0.0-0.8)	0.01 (0.01-0.02)	5.8 (0.3-7.2)	1.7 (0.4-4.4)
Ashanti						
Raw	32.1 (21.0-43.0)	0.05 (0.0-0.2)	0.0	0.02 (0.0-0.1)	62.6 (1.1-99.1)	0.7 (0.1-0.9)
Greater Accra ***Raw***	28.6 (15.9-42.0)	0.0	0.0	0.0	0.9 (0.4-1.6)	0.8 (0.4-1.7)

Note: Ranges are given in parentheses

Table 18 ISO 7301 Rice Specification (summary)

	Milled rice (%)	Milled parboiled rice (%)
Organic matter	0.5	0.5
Inorganic matter	0.5	0.5
Damaged kernels	3.0	3.0
Red kernels	4.0	4.0
Red streaked kernels	8.0	8.0

4. FINANCIAL ANALYSIS

4.1 Operating costs and turnover

The operation of the mills depends on the availability of paddy and the willingness of traders to mill their produce. On average, the mills are operated for six months in a year from December through May. During this period, steel hullers mill between 1.6t and 4.1t of paddy a day while rubber roller mills mill between 2.6t and 5t a day. An estimate of the total daily operating cost of operating a steel huller mill was approx. ¢7,000 which was observed to be about a third of that for rubber rollers (Table 19).

Cost of spare parts (sieves, belts, shaft, etc) and electricity constituted about 50% of the total cost of operation of the mills. Because steel huller mill owners depended on locally fabricated parts the total cost share of these spares was 15% notwithstanding the frequent replacement. In contrast, the cost of replacement parts for rubber roller mills which were imported was about seven times that of the steel huller mills and made up about 37% of the total cost of operation. In relation to the installed capacities of the mills, the motors for the steel hullers were higher thus leading to energy wastage. Consequently, the cost of electricity was observed to constitute about 35% of total operation cost for steel huller mills. In absolute terms, energy costs did not significantly differ between the two mill types.

In relation to the quantity of rice milled per day of 2.7t and 3.8t for the steel huller and rubber roller mill, respectively, cost of milling was estimated at ¢2.68 and ¢5.22 per kilogram of paddy. Operations currently being carried out attract about ¢17.4 and ¢24/kg paddy for steel hullers and rubber rollers respectively. Consequently, millers make an average of ¢14.73 and ¢19.25 on each kg of paddy milled by the steel hullers and rubber rollers, respectively (Table 19).

Table 19. Daily cost of mill operation

Item	Type of mill			
	Steel huller (n=27)		Rubber roller (n=3)	
	Mean	Min - Max	Mean	Min - Max
1. Spare parts:				
Bearings	437.35	167 – 667	533.33	267 – 667
Belt	92.45	14 – 250	136.93	127 – 142
Blade	195.28	89 – 400	0.00	-
Rollers	0.00	-	3,777.78	3,333 – 4,000
Shaft	183.46	100 – 472	458.33	2,500 – 6,667
Sieves	201.89	106 – 533	2,500.00	1,667 – 3,167
Total cost	**1,110.43**	-	**7,406.37**	-
2. Lubricants	288.99	214 – 428	664.29	420 – 820
3. Electricity	2,546.34	1000 – 9000	3,333.33	1,333 – 6,667
4. Rent	536.68	133 – 4000	900.02	83 – 3,330
5. Husk disposal	733.34	120 – 480	1,000.02	660 – 3,300
6. Other charges	390.00	102 – 560	106.00	82 – 1600
7. Depreciated value of mill and motor	781.25	-	1,562.50	-
8. Operator's salary	855.30	680 - 1002	4,866.67	825 – 6,200
Total daily operating cost:	**7,242.33**	-	**19,839.20**	-
Daily throughput(kg paddy)	2,700	-	3,800	-
Milling charge (¢)	46,980	-	91,200	-
Bran sales (¢)	0.00	-	1,800	-
Total returns	**46,980**	-	**93,000**	-
Profit	39,758	-	73,161	-
Profit (cedis/kg)	**14.73**	-	**19.25**	-

4.2 Cost of equipment and spare parts

New, imported, steel hullers were found to be stocked in Accra, Tamale and Kumasi. Imported dehullers sold at between 800,000 - 2.6 million cedis, depending on model. A locally fabricated huller was available in Kumasi at 450,000 cedis. Prices are detailed in table 20 below:

Table 20. Cost of mill spare parts (cedis)

Screens: Taiwan	75,000 pair
China	60,000 pair
Local	25,000 pair
Screw: Taiwan	500,000
Local (Nigeria)	110,000
Rubber rolls	120,000 each
Rubber Roll Mill Taiwan	10-15 million

Profitability of mill operations

Mill operation in northern Ghana has been thought to be profitable over the years due mainly to increase in custom. In the Upper East region, the large scale ICOUR mill is a potential competitor to the small scale steel huller mills. However, it operates only when it has enough paddy to justify its operation. Therefore, the more customers decide to mill small quanitities, enough for sale on a given market day, the more they patronise the small mills. Consequently, all millers interviewed, except two experiencing relatively high replacement costs of parts to their ageing mills, agreed that there was an increasing trend in profits over the years due mainly to increase in custom. A similar reason was given by their counterparts in the Upper West region. The inactivity of the Nasia Rice Company large scale mill in Tamale has boosted the operations of the small scale mills in the town. Incidentally, about 60% of Ghana's rice is produced in this region. Mill owners consider this situation very opportune and predict a more profitable future in the business especially that the government is making all efforts to promote rice production.

In Southern Ghana, rice millers are unsatisfied with their returns from the business. For example, a customer from the Brong Ahafo region, over 100 km away from Kumasi, may transport over 50 bags paddy for milling. At Kumasi, the mill owner may have to pay off the transport charge hoping to be reimbursed after milling. Sometimes the trader may refuse to sell the milled rice when the price is not satisfactory but store it with the miller for sale at a later date. In the process, she locks up the transport and milling charges and effectively reducing storage space for potential customers. They do not foresee an improvement in profits but will remain in business due to heavy investment already made.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Most of the rice produced in Ghana is processed by small-scale operators. Simple technology, available on a custom basis, generates considerable employment and profits for the informal sector. Ease of entry is substantial due to the relatively low initial investment costs.

While it appears there is a market for the product, otherwise there might be more pressure on the rice processors to improve their practices, it is also possible that millers and parboilers do not have access to information on how to go about changing their methods.

Information gathered during the survey does indicate that a number of improvements could be made to operating procedures and these are detailed below. Preharvesting factors and harvesting practices have an impact on the quality of milled rice although changes in this area are outside the scope of this study.

5.1.1 Mills

- Most operators have not been trained in use and adjustment of mills. This can affect rice quality and quantity.
- Locally fabricated spares are often of poor quality.
- Techniques such as double pass are only employed in Upper West.
- Mills with aspirators are very rare.
- Mills are under utilised

5.1.2 Millers' associations

- Rice millers' associations are said to exist but may not see improving product quality and working conditions as part of their role.

5.1.3 Commercialisation

- No millers were found to be buying paddy and milling it for retail sales. There is currently little incentive for them to maintain and adjust their mills to produce good quality rice.

5.1.4 Parboiling

- If family labour was valued at its opportunity cost, parboilers in the Northern region would be making a loss on each bag of rice sold.
- There is considerable regional variation in quality resulting from minor differences in technique.
- Firewood is a big problem.
- Water availability and quality is a problem.
- Working conditions are a problem.
- Parboiling is almost exclusively carried out at village level. The only commercial parboiling plant is of very large capacity.

5.1.5 Financial aspects

- No records appear to be kept of throughput, takings and expenditure making it difficult to obtain an idea of capacity utilisation and profitability.
- According to data from the survey, although the steel huller mills make a lower profit per bag than the rubber roll mills their daily operating costs are about one-third that of rubber roll mills.

5.1.6 Product mismatch

- There appears to be a market for local rice even though imported rice is said to be preferred.

5.2 Recommendations

5.2.1 Mills

- Training of operators in use and adjustment of mills would improve rice quality.
- Upgrading of locally fabricated spares to improve quality.
- Techniques (double pass) employed in Upper West could be transferred to other regions.
- Mills with aspirators should be encouraged or, if separation of husk and bran is not considered important, the Engleberg type mills could be redesigned without a screen thus eliminating the need for screens in this type of mill.

5.2.2 Millers' associations

- Dedicated rice millers associations could provide a vehicle for discussing and introducing improved practices.
- They could also arrange purchase and distribution of spare parts.
- They could raise awareness of working conditions and health risks.

5.2.3 Commercialisation

- If some millers were to buy paddy and mill it for retail sales and market high quality rice then other millers might realise the importance of producing high quality rice.

5.2.4 Parboiling

- Need to investigate the implications of the low opportunity cost of labour and low rice prices in the Northern region .
- Regional variation in quality indicates that technology transfer could improve quality in the Northern region.
- Upscaling might be possible. Probable drawbacks would be paddy supply and drying space. This would need a full economic and social assessment.
- The introduction of energy-efficient stoves, possibly fuelled by rice husk, could assist in areas where firewood shortages are a problem.
- Improved threshing practices could improve the cleanliness of paddy and allow reductions in the quantity of water used for washing paddy.

5.1.5 Product mismatch

- Recommendations from the marketing study may explain why people are prepared to accept a poorer product, and help develop a way forward.

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