EVALUATION OF RICE MILLING AND QUALITY OF RICE IN GHANA

BY

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DECLARATION

I declare that except for references to works, which have been duly sited, this thesis is an original research carried out by me under the supervision of Prof. Samuel Sefa-Dedeh, of the department of Nutrition and Food Science, University of Ghana, Legon.

....	....
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DEDICATION

(i) To the Ever-present God, My Lord, *for making all things beautiful...*

(ii) To the memories of my grandmother, Mama Akosua Botwe, *who instilled in me the love for learning*

(iii) To my mum, Mad. Felicia Tekaa and my *entire* family, *for always standing 'with' me.*

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ABSTRACT

The consumption of rice is on the increase in Ghana. However, local rice is said not to compare well with imported rice. The need to make local rice more competitive is recognized in the light of the increasing role of quality as an important factor of economic competitiveness. This work was aimed at studying the pre- and post-harvest technologies for rice, studying rice handling, management and marketing systems, assessing the performance of rice mills in Ghana and characterising the rice varieties based on the three grain types. Three sets of questionnaires were used to obtain information on pre- and post-harvest factors from rice farmers, middlemen and millers in the Greater Accra, Volta and Eastern regions. Paddy and raw milled rice samples obtained from farms and mills were analysed for quality and grade. Results show that pre- and post-harvest activities are carried out manually. Farmers and middlemen do not have any means of removing high-density foreign materials such as stones from paddy rice. The temperature and relative humidity during drying and storage are not controlled. Moisture content of rice is measured subjectively. Milled rice is sold mainly in small units on the market by middlemen and is not graded. Small-scale operators who have not had any formal training in the use and adjustment of mills process (mill) rice. Small- and medium-scale, single pass, rubber roller mills predominate in the study area. All mills produce under capacity with milling yields of 45-75 %. The mills do not have precise maintenance schedule. Milled rice from mills could be classified as Ghana rice grades 1 to 5 based on content of extraneous matter, discoloured and chalky grains. Broken kernels of samples ranged between 21-81 %. Thus in terms of percentage broken, mill rice does not fall within specifications of Ghana standard for milled rice. Samples had lower grade than the lowest grade of GS 61: 1990. The very high percentage of broken kernels makes local rice less competitive. Results also indicated that rice samples could be classified as long, medium and short grain types based on standard specifications of Ghana (GS 61:1990), Codex Alimentarius, and the FAO. Most mills produce low degree milled rice. Bulk density values ranged between 793.7 kgm^{-3} for Wita 9 to 848 kgm^{-3} for Emo korkor. This was partly affected by moisture content ($r^2 = 0.21$). Colour, translucency, fat, protein, and ash were significantly different ($p < 0.05$) among the samples. Protein, fat and ash content ranged between 6.45-10.45 %; 0.11-1.56 %; and 0.24-0.79 % respectively. Rice kernels exhibited alkali-spreading values of 2-6 and were mostly high amylose varieties. TOX 3108 recorded the highest pasting temperature of 82.6°C while the lowest pasting temperature of 62.3°C was recorded by TOX 18447. Rice samples showed peak viscosity of 760-1165 BU and relatively high viscosity (755-1040 BU) of the cooked paste on cooling to 50°C except Emo korkor, which had cooled paste viscosity of 720 BU, indicative of medium and short-grain types. The rice varieties overlap in the physicochemical properties of the 3-grain types. A number of improvements could therefore be made to rice production and processing procedure in Ghana.

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1.0 INTRODUCTION

1.1 ROLE OF RICE IN GHANA'S FOOD ECONOMY

Rice (*Oryza sativa*, L) is an important staple crop, supplying the major foods for more than half of the world's population (Hawksworth, 1985). Worldwide, it is the second most important cereal. In terms of production, rice is the third most important in Ghana, after maize and sorghum (Chinery and Bakaweri, 2000) and contributes 10 % of the total cereal production. During the 1980s, annual rice production averaged about 63 000 metric tonnes. It increased from 81 thousand tonnes in 1990 to 248 thousand metric tonnes in 2000 (SRID, 2001). This growth was generally the result of the intensive extension activities carried out by the Ministry of Food and Agriculture (MOFA), the release of improved rice varieties by agricultural research institutions which increased yield per acre, the adoption of new varieties by farmers, availability of agro-inputs and investments in land development (Chinery and Bakaweri, 2000).

Rice production, which is carried out in all the ten regions of Ghana (Oteng, 1997) (Table 1) has seen considerable increase in recent years, compared with the other cereals. In the year 2000, output of rice increased by 18.6 % compared with 7.0 % increase in the output of millet and decline in output of maize and sorghum over the level of 1999 (ISSER, 2000). Though the total production of the four major cereal crops in the country (maize, rice, sorghum and millet) decreased by 3.7 % in 2001 compared with 2000, the production of rice increased by 18.9 % over the same period whilst the production of maize declined by 7.4 % and millet by 10.7 % (ISSER, 2001). The situation should, thus, improve the marketability of the local rice vis-à-vis imported rice which has a bigger share of the domestic market.

Table 1: Rice production, cropped area and average yield in Ghana by region – 2000

Region	Production (metric tonnes)	Cropped Area (Ha)	Average yield (MT/Ha)
Western	18 598	14 745	1.26
Central	0	0	0.00
Eastern	24 600	12 300	2.00
G. Accra	8 910	1 980	4.50
Ashanti	11 040	4 860	2.27
Volta	35 070	10 690	3.28
Brong Ahafo	2 856	4 657	0.61
Northen	72 960	30 400	2.40
Upper West	9 281	4 103	2.26
Upper East	65 379	31 421	2.80

Source: SRID, Min of Food and Agriculture, 2001

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, mainly for women as they are involved throughout the production chain from planting to trading. The traditional produce marketing system in Ghana for local staple food, including rice, is principally governed by competitive systems at wholesale and retail levels including middlemen (Kudolo, 1994). Thus, rice farming and processing also provide employment for many people.

Rice also plays a central role in Ghana's food consumption. Over the years, rice has become one of the most important food item for all Ghanaians (Orraca-Tetteh, 1989).

A rapid dietary shift to rice, particularly in the urban centres has been experienced in recent years (Bam *et al.*, 1998; Manful *et al.*, 1998). A combined analysis of the results of a study by Bam *et al.* (1998) in Tamale, Kumasi and Accra showed that rice ranked next to maize as the most important staples. Analysis of the same data by city revealed that rice is the most important staple of most households in Accra. They also found out that, plain rice with stew was the most popular form of the preparation in Ghana. Further, apart from cassava and kenkey, Ghanaian urban consumers spent more on rice than any of the starchy staple foods over the period of 1987 to 1992. The situation in rural areas was similar (GLSS, 1). These results thus confirm the increasing popularity of rice relative to other staples and give credence to the observations by Nyanteng (1987) that rice has assumed a growing importance in Ghana.

Rice consumption increased from 7.4 kg per caput/annum between 1982 and 1985 (WARDA, 1986) to 13.3 kg caput/annum in 1996 (SRID, 1996) resulting in a total annual consumption of 289 thousand tons of milled rice. However, Ghana, like other West African countries, has not attained self-sufficiency in rice production (ISSER, 2001; SRID, 2001; GSS, 2001). For instance, in the year 2000, 248 thousand metric tons of paddy rice was produced (SRID, 2001) in Ghana. This generated a milling output of 154 thousand metric tons, leaving a demand gap of 168 thousand metric tons of milled rice, which was filled with imports (GSS, 2001) (Table 2). Currently, it is estimated that close to 70 % of the rice consumed is imported (SOFRECO, 1996), valued at $ 100 million (MOFA, 2000). The continuing increases in per capita consumption points to a growing rice demand. Hence substituting locally produced rice for imports would release scarce foreign exchange for other purposes.

Table 2: Domestic Rice Production and Imports (1995-2000)

Year	Production*[1] (1000 MT)	Milled rice imports (1000 MT) [2]	Total milled rice consumed (1000 MT)
1995	221.3	94.27	231.45
1996	215.7	34.89	168.62
1997	197.1	37.52	159.72
1998	281.1	781.85	956.13
1999	209.8	69.14	199.22
2000	248.7	168.27	322.46

Sources: (1) SRID (Statistics, Research and information Directorate), Min of Food and Agriculture, February 2001.

(2) Ghana Statistical Service (GSS), Accra

*Paddy

1.2 CONSTRAINTS IN THE RICE INDUSTRY IN GHANA

The rice industry in Ghana, though growing gradually, has many constraints to its growth. The rate of expansion of the industry has been unable to satisfy local demand. With consumption growing at a steady rate of 6 % per annum, production rate has been slower, almost flat, with fluctuations of about 36 % in some years. The country has a huge potential to increase rice production. However, trade liberation policies from the early 1980s have stifled the industry through competition (Chinery and Bakaweri, 2000).

Obsolete Technology:

Local rice is said not to compare well with imported varieties (Bam *et al.*, 1998) due to the presence of stone and other extraneous matter, which are as a result of poor harvesting, and processing methods. Combined harvesters and improved village level rice threshing technology are not available in major rice producing areas. The use of threshing floors is also uncommon. Rural farmers, therefore, thresh panicles on the bare ground, resulting in contamination by dust and stones. Currently, the domestic market does not offer premium prices for quality paddy rice. Hence farmers who could invest in quality improvement technologies have no incentives to do so.

Consumer Preferences:

Generally, most consumers prefer single grained rice. However, all rice types – imported, local, white, brown, sticky and single grained have distinct local dishes for which they are best suited. The development of local rice varieties has not adequately considered these factors because research has focused more on problems of low production, and yield as well as disease resistant varieties (Oteng, 1997). There is the need therefore, to research into the development of different varieties as well as research to classify available and new varieties to be developed into suitable groups based on cooking, processing and end-use characteristics.

Processing Issues:

Rice processing is the initial post-harvest activity undertaken to prepare rice for consumption. Processing of rice in Ghana includes threshing, drying, parboiling and milling. A study by Manful *et al.*, 1998 identified the following factors as affecting rice quality in northern Ghana:

I. Much of the rice is grown from impure seeds, with high levels of admixture, resulting in uneven grain maturity at harvest

II. Many non-irrigated 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

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

IV. Grain harvested by combined harvester have a larger proportion of broken grains and organic contamination (weed seed, chaff etc)

V. 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 mud and stones.

VI. 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

VII. Over drying, either pre- or post-harvest and subsequent cracking of the grain results in high percentage of brokens in milled rice

These problems inevitably affect the final quality of milled rice. Unfortunately, most of the mills do not have pre-cleaners that would remove stones and organic matter from rice during milling. The high percentage of broken rice in locally milled rice is also influenced by other factors apart from poor processing practices. Steel hullers are mainly used in the northern sector of Ghana, resulting in low head and total rice recovery, particularly in raw rice milling. In the southern sector, use of rubber roller mills predominates. However, because millers are not trained in the adjustment of mills, and also, due to the fact that some of the mills are relatively old, the production of high percentage of broken grains is experienced.

In the northern sector, parboiling of rice is done prior to milling. It has been shown that (Manful *et al.*, 1998; Yakubu, 1999) some of the women parboilers do not remove extraneous matter from paddy before parboiling hence parboiled rice produced is usually with poor quality- with dark colour and high percentage of impurities, including stones.

Marketing Issues:

Locally produced rice, in general, is not branded or graded and is mixed with a high percentage of foreign matter. It also has a high starch content, high moisture content and a higher percentage of brokens compared with the imported ones (Manful *et al.*, 1998). This quality constraint has resulted in parallel markets for the local and imported types with different demand and supply responses. The demand for locally produced rice is low particularly in the urban centres (Nyanteng, 1987; Bam *et al.*, 1998). However, some commercially processed raw milled rice produced in the irrigated rice ecology is both branded and graded and marketed competitively alongside imported products. This rice is reported to be sought after and preferred by a certain segment even at a price premium over imported brands (Conway, 1997).

The seasonal variation in the supply of local rice is a major constraint to the marketing of rice. During the bumper season, farmers are obliged to sell to private traders at low prices (Kudolo, 1994) because of lack of proper storage and processing facilities and the presence of assured market outlets internally and externally. The marketing facilities will help prolong the shelf-life of the produce and help remove the great price fluctuations experienced between glut season and lean season. Since all rice produced is sold in the period of glut, local rice tends to be scarce in the planting or lean season. The price of paddy is therefore dependent on the supply of available paddy rather than paddy quality.

The marketing of locally milled rice is a simple one, where local traders continue to use traditional marketing strategies. Therefore, the superior quality of imported rice, packaging and more aggressive market promotion has compounded matters for locally produced varieties.

The need to make local rice more competitive is therefore recognized, particularly in the light of the increasing roles of quality as an important factor of economic competitiveness and also because the Ghanaian rice consumer has become more sophisticated with preference of rice with very high quality. With rice production now increasing each year (MOFA, 2001), there is an urgent need to know the adequacy of processing techniques and technologies. Information is also required about the reasons for the quality of rice obtained as well as opportunities for upgrading.

1.3 Objectives

This work is aimed at evaluating the rice milling process in Ghana, and specifically:

1. To assess the pre-and post-harvest technologies for rice
2. To evaluate rice handling, management and marketing systems
3. To assess the performance of rice mills in Ghana, and
4. To characterise the rice varieties based on the three grain types

2.0 LITERATURE REVIEW

2.1 FORMS OF RICE

Rice is the seed of a semi-aquatic grass plant, *Oryza sativa* that is native to India, Southeast Asia and China. Cultivation of the rice crop begins in early spring with breaking up the soil to prepare for planting (RCMD, 1989). In Ghana, it begins in the raining season (March to July). In 100 to 180 days, depending on the variety and the climate, the grain is ready to be harvested (Dziezak, 1991).

Rice that has been harvested from the plant with its hull (husk) intact is known as rough or paddy rice. The paddy is dried to appropriate moisture content and either stored until it is sent to the mill, or milled immediately. Depending on the extent of processing different forms of rice is obtained. (RCMD, 1991). Brown rice is the least processed form: only the hull has been removed. The rice still retains the germ and seven bran layers, rich in vitamins and minerals, which contribute a brown colour. However, not all rice with the hull removed is brown in colour. White milled rice, also known as polished, table or milled rice has had its bran and hull layers removed from the brown rice, leaving the starchy endosperm. It is the most common form of rice and has a longer shelf life than brown rice. Parboiled or 'converted' rice has been hardened by a special steam pressure process before milling. Precooked rice is regular milled rice, which has been completely cooked and dried. The resulting porosity of the grain enables fast rehydration and therefore, a shorter cooking time (Adair, 1980; Dziezak, 1991).

2.2 RICE QUALITY AND GRADE CLASSIFICATION

Rice quality is determined using a combination of subjective and objective factors. These are ranked in importance in the evaluation of rice quality.

2.2.1 Concepts of Rice Quality

Rice, unlike most other cereals is consumed as a whole grain. Therefore physical properties such as size, shape, uniformity and general appearance are of most importance. Furthermore, because most rice is milled, the important physical properties are determined primarily by the milled endosperm.

Rice quality is influenced by characteristics under genetic control, environmental conditions, and processing techniques, in the case of purity. In the latter case, characteristics are principally a function of handling, storage and distribution. The genetic make-up of a particular variety dictates to a large degree, the grain quality characteristics. Marked differences in rice quality also occur as a result of environmental conditions and cultural practices during growth. These factors may under some circumstances have a greater impact on quality than inherited traits. (Mutters, 1998).

2.2.2 Physical Characteristics of the Rice Grain in Relation to Rice Quality

The rice grain is conoelliptical in shape and there is variation in the size and shape. The physical characteristics of rice grain have an important role in the milling and nutritional properties (Barber *et al.*, 1980) and since rice is marketed according to grain size and shape, the physical dimensions, weight and uniformity are of prime importance (Young, 1998). Grain type categories are based upon three physical qualities: length, width and weight. Variations of each of the three grain types must conform to rather narrow limits of size and shape (Table 3).

Table 3. Range of grain sizes and shape among typical US Long-, Medium- and short-grain rice

Type	Form	Length (mm)	Width (mm)	Weight/1000 (g)
Long	Brown	7.0 – 7.5	2.0 – 2.1	16 – 20
Medium	Brown	5.9 – 6.1	2.5 – 2.8	18 – 22
Short	Brown	5.4 – 5.5	2.8 – 3.0	22 – 24

Rice is classified as long-, medium-, and short-grain based on kernel length, and shape (Adair, 1980). Industry also recognizes a fourth category called 'specialty rice' which is distinguished by characteristics other than kernel dimensions and shape; these include varieties such as jasmine, basmati, Arborio and sweet glutinous.

The standard of rice differs from place to place. The International Rice Research Institute (IRRI) uses the following scale for size of brown rice: extra long, > 7.5 mm; long 6.61 to 7.5 mm; medium, 5.51 to 6.60 mm; and short, < 5.50 mm. Grain shape is characterized based on length to width ratio: slender, > 3.0; medium, 2.1 to 3.0; bold 1.1 to 2.0 and round, < 1.0.

The Codex Alimentarius Commission committee considering the draft standard for rice proposed the following classification for milled rice based on length-to-width ratio; long-grain, < 3.1; medium-grain, 2.1 to 3.0; and short-grain, < 2.0 (Codex Alimentarius Commission, 1990). Dziezak (1991) classified milled rice as follows:

I. Long-grain rice is 6.0 to 7.0 mm in length and have a comparatively high amylose content

II. Medium-grain rice measures 5.0 to 5.9 mm in length, is plump in shape, and has a lower amylose content than long grain

III. Short-grain varieties are those less than 5.0 mm - are somewhat rounded in shape and have an amylose content similar to that of medium grain rice

In addition to the above scheme, industry classifies rice into Japonica and Indica types, based on cooking characteristics. Japonica, originally from lowland Japan and Manchuria, includes both short- and medium-grain types; when cooked, it is sticky, chewy, moist and clingy. Indica is long-grain rice that originated in India, China, Thailand and Philippines; it yields a dry, fluffy texture when cooked and the grains remain separate (Dziezak, 1991).

2.2.3 Physico-chemical Properties of Rice in Relation to Rice Quality and Classification

The physicochemical factors which play important role in determining the cooking and processing quality of milled rice include alkali spreading value, gelatinisation temperature, amylographic cooked paste viscosity, water absorption capacity and birefringence end point temperature (BEPT). The amylose-amylopectin ratio is the major component of milled rice which influences the physicochemical factors mentioned above. Juliano (1984) found out that, there is positive correlation between amylose content and the amylographic gelatinisation temperature. McKenzie (1994) indicated that differences in the amylose content and gelatinization temperatures are attributed in part to the differences in the environmental conditions in which the crop is grown, particularly temperature. Priestly (1977) showed that the degree of stickiness of cooked rice relate to solubility with soluble amylopectin.

Typical long grain varieties for cooking and processing are characterized and classified by a relatively high amylose content (23-27%); a slight to moderate spreading reaction of whole kernel milled rice in 2.0% KOH solution, intermediate gelatinisation temperature (70-75°C) and a moderate water uptake at 77°C. Generally, indica rice varieties contain more amylose than the japonica varieties. The amylose content is used to predict the cooking quality of rice. A high amylose content rice variety gives dry fluffy cooked rice whereas low amylose content produces sticky glutinous rice.

Amylograph pasting characteristics of the typical long grain type usually show an intermediate peak viscosity (700-900 BU) and relatively high viscosity (759-950 BU) of the cooked paste (Juliano, 1984). Water absorption and dissolution start at lower temperature in the starches with low gelatinisation temperature. Non-waxy starches give lower values than waxy starch and continue to absorb water above its gelatinisation temperature. In contrast, the maximum absorption value of waxy starch is due to its gelatinisation (Juliano, 1984).

2.3 RICE POSTPRODUCTION SYSTEM

The post-harvest system encompasses the delivery of crop from the time and place of harvest to the time and place of consumption, with minimum loss, maximum efficiency and maximum return for all involved (The Hidden Harvest, 1976). The postproduction operations account for more than 55 % of the economic value of the agricultural sector in developing countries and up to 80 % in developed countries (Mazoud, 2001). They are the basis of socioeconomic development in rural areas and of critical importance in meeting the food security and nutritional requirements of populations (Mazoud, 2001).

Grain postproduction system is a series of processes beginning from harvesting to consuming rice, which include such operations as harvesting, threshing, cleaning, drying, storing, transporting and processing (He Yong and He Yong-sheng, 1996).

2.3.1 Rice Harvesting Methods

In many countries, rice ears are cut by hand. A special knife is frequently used. To harvest denser varieties (500 stems/ sq metre instead of 100) a sickle is used mainly on a generally wetter produce. For example, more than 95 % of paddy in Zhejiang province is harvested using the manual sickle (He Yong and He Yong-sheng, 1996). Only a few regions have a better technological and economical condition and developed enterprises that use combines. The farmers in Orrisa, India use mostly traditional methods for harvesting paddy with sickles, which vary in their size and curvature depending upon the locality (Dash *et al.*, 1997). A study conducted at Sidenreng Rappong, a major rice producing area (Lando and Najamuddin, 1995) showed that farmers predominantly used the unserrated sickle, with some using the serrated sickle. The highest mean capacity was 0.83ha/sickle with the serrated sickle, which was 32.7 times higher than the unserrated sickle.

Work times in sickle harvesting however, remain high: 100 to 200 man-hours per ha for cutting and stocking. Alternatively, harvesting of matured fields is done mechanically by means of combine harvesters, animal drawn machines, or tractors equipped with cutter bar.

In parboiled rice consuming areas, paddy is harvested when the grain becomes fully mature thus, about 18-20 % wet basis (w. b.) moisture content or less. Harvesting of rice at such low moisture contents are said to reduce otherwise long drying hours and labour problems (Dash *et al.*, 1997). But grain shattering and losses due to birds were estimated to range between 0.5 and 1.8 % (RESC, 1994b). However, the varieties of rice which are milled in the raw form are harvested at a comparatively higher moisture content of 21-24 % (w. b.) when there are about 2-3 % green grains on the stalk (Dash *et al.*, 1997).

Differences of 5 to 10 % (w. b.) moisture content have been observed on grains on the same plant and even on the same panicle. If harvest were delayed for all kernels to mature, the early maturing kernels will become overripe and overall quality will decrease. Overripe kernels, generally identified by moisture content below 22 % MC for early maturing varieties in California, are subject to field cracking if not harvested promptly when they are mature (Luh, 1980). Ruiz (1965) showed that the average grain losses at different harvesting times were: 1 week before maturity – 0.77 %, at maturity 3.35 % and 1, 2, 3, and 4 weeks after maturity were 5.63 %, 8.64 %, 40.70 % and 60.46 % respectively. In Bangladesh, harvesting losses are due to shattering and handling (Dash *et al.*, 1997). Toquero (1975) reported that depending upon the number of times harvested stalks of rice are handled from the field to the threshing yard, shattering loss was up to 7 %.

2.3.2 Rice Threshing Methods

After being harvested, paddy bunches may be stacked on the plot (Miah *et al.*, 1999). This in-field storage method results in pre-drying of the rice ears before threshing; the purpose of which is to separate seeds from panicles (Mutters, 1998).

The traditional threshing of rice is generally made by hand: bunches of panicles are beaten against a hard element (e.g. a wooden bar, bamboo table or stone) or with a frail. The outputs are 10g to 30g of grain per man-hour according to the rice variety and the method applied. Grain losses amount to 1-2 %, or up to 4% when threshing is performed excessively late; some unthreshed grains can also be lost around the threshing area.

In many countries in Asia and Africa, and in Madagascar, the crop is threshed by being trodden underfoot (by humans and animals); the output is 30 kg to 50 kg of grain per man-hour. The same method, but using a vehicle (tractor or lorry) is also commonly applied. The output is a few hundred kg per hour. This method results in some losses due to the grain being broken or buried in the earth (Proctor, 1994). The separation of grains from panicles occurs due to the rubbing action, impact and stripping. The rubbing action occurs when paddy is threshed by trampling by man, animal or tractors while impact action takes place during drum beating (Miah *et al.*, 1999).

In the northern sector of Ghana, threshing of paddy is carried out by beating panicles of rice with sticks or by treading on the stack of harvested crop. Panicles may also be beaten against tanks, barriers and boxes (Yakubu, 1999).

Rice threshing using the pedal thresher has been found to perform better in respect to threshing output, grain damage, unthreshed grains (Miah *et al.*, 1994) and threshability (Miah *et al.*, 1999). In the same study (Miah *et al.*, 1999), it was found that stacking rice 0-5 days and threshing with pedal thresher would be an appropriate method of rice threshing that would minimize threshing losses and produce quality paddy for both seed and food purposes. In another study, (He Yong and He Yong-sheng, 1996), the three main threshing methods in Zhejiang province were studied. It was found that the loss in using pedal thresher is the least and using combine harvester is highest work efficiency.

The variety and threshing method have been shown to have significant effect on threshing output. Campbell (1976) reported the threshing output of pedal threshing to be 40-54 kg/hr. The IDRC (1976) reported that the threshing output of pedal thresher was 80-100 kg/hr. The average threshing output of pedal thresher, 103.40 kg/hr obtained by Miah *et al.*, (1994) was two times higher than Campbell's findings and a little higher than reported by the IDRC.

Combine harvesters combine the action of reaping and threshing. According to the type of machine used, and especially to their working width, capacities range from 2 to 15 hours per hectare.

2.3.3 Rice Drying

Freshly threshed rice may spoil rapidly when exposed to high temperature, high moisture content, moulds and foreign matter. Prompt cleaning to remove all straw, chaff, joints and weed parts will speed drying and lessen danger of spoilage and insect damage.

Sun drying of paddy is a common practice, particularly in the tropics. Threshed grains generally are sun-dried on concrete and other hard surfaces, or in grain driers. Traditionally, drying rice in the sun poses no particular problems. However, in the case of rice harvested in the dry season, the problem is to control drying to prevent excessive heating and hydric stress in the grain whereas, in rainy days, drying is often delayed causing degradation of grain (Dash *et al.*, 1997; Ahmed and Mazed, 1996). Besides, open sun drying has its own disadvantages like losses due to wind, birds and scattering. Drying losses are high in the rainy season. Mechanical drying can reduce losses as well as human drudgery. Miah *et al.*, (1987) showed that artificial drying below 52°C does not affect the germination of paddy.

In an experiment to determine the influence on the grain quality under delayed drying condition, it was found (He Yong and He Yong-sheng, 1996) that if drying is delayed, the average weight of 1000 grains of early and late maturing rice varieties is decreased by 0.32 g, germination percentage is reduced by 5.86 % whilst the rate of broken kernels increased by 5.96 %.

In Bangladesh, sun drying includes spreading wet paddy over the hard, levelled and mud plastered dry floor with a thickness of 10 to 15 mm (Ahmed and Mazed, 1996).

The grain is usually stirred by foot. The thickness is usually irregular over the drying floor due to ridges formed during stirring.

Rice drying in the sun on drying floor is also a common practice in Ghana (Manful and Andoh, 1989). Dei (2002) reports that 7 % of farmers in the Hohoe district dried their produce on cut stocks of rice, 70 % on polyethylene sheets whilst 23 % dry paddy on concrete floors.

For rain-fed rice harvested in periods of high relative humidity, some development projects have studied and extended models of drying floors. Grain is arranged carefully on the restricted surfaces of purpose-built drying floors and the progress of the operation is carefully controlled. Results show that paddy can be dried (from 24-26% moisture content to 14%) in beds 50-100 mm thick at a rate of 3.3 kg/ m^2/h if the grain is regularly turned or 1.9 kg/ m^2/h if the grain is not turned.

Under conditions of maximum insulation, rice may attain a temperature of 60°C and the rate of drying is sufficiently high to provoke cracking and losses in milling. The sun drying rate is reduced by covering the grain between mid-day and 3pm (in the experience of IRRI) when the weather is particularly sunny thereby reducing cracking by 25 %.

2.3.4 Paddy or Rough Rice Storage

Rice can be stored satisfactorily in the hull (paddy) after it is dried to 13 to 14% moisture, but special precautions are needed to prevent insect and rodent damage. Good storage practices prevent rice quality loss by:

a) Keeping rice below a moisture which corresponds to a 65% equilibrium relative humidity

b) Keeping rice temperature within 10°C of the average monthly air temperature and below 60°F as long as possible during the year

c) Designing and operating aeration system to maintain uniform rice moisture and temperature

d) Storing only well cleaned rice (Young, 1998).

Storage changes, or ageing, occur particularly during the first three to four months after harvest and are also known as 'after-harvest ripening' (Juliano, 1985b). The grain constituents probably equilibrate to their more stable physical form, which results in a harder, creamier coloured grain (Yap *et al.*, 1990). After-harvest ripening is accompanied by a higher yield of total and head milled rice. Stored rice expands more in volume and yields more flaky cooked rice with less dissolved solids in the cooking water than freshly harvested rice (Juliano, 1985b).

The rice grain is very hygroscopic because of its starch content and equilibrates with the ambient relative humidity. The safe moisture content for storage is generally considered to be 14 percent in the tropics (Cogburn, 1985). Storage pests (insects and micro organisms) and rodents cause losses in both quality and quantity of the grains (Cogburn, 1985). However, gross composition is not affected by storage, but vitamin content decreases progressively (Juliano, 1985b).

Rice is stored as rough rice in most of the tropics but as brown rice in Japan.

2.3.4.1 Rice Storage Methods

The structures used to store rice are extremely varied. The choice of building materials and the size and type of structure depends upon the specific needs of the builder, the types of material available to the builder and the financial resources available. In some areas, pits are dung in the dirt floors of huts; lined with straw mud brick or other material; filled with grain and provided with some sort of cover. In developed countries, bins, silos or large warehouses are constructed of metal or concrete. Regardless of the form of storage, its primary purpose is to protect the rice from weather and pests (Cogburn, 1985).

A study by Dei (2002) revealed that 4 main storage methods are practiced in the Hohoe district of Ghana. Thirty percent (30 %) of farmers' stored rice in polypropylene poly bags, 37 % use jute bags, 25 % uses mud silos while 8 % use baskets. Storage of seeds in jute bags was preferred to other methods due to its better aeration during storage, and resulting better viability. The storage structures were however, found to be prone to rodent attack in exception of mud silos.

Chenchenkun, storage structure made of mat with openings at top and bottom, is used in northern Ghana (Akowan, 1998), in addition to traditional barns and cribs. The use of chemicals is possible in this structure but fumigation is not effective as the structure is not airtight. It is also prone to rodent infestation.

In India, farmers commonly use the following types of traditional storage structures with 0.1 to 1.5 metric ton capacity:- Straw storage structures (*Puri, Malei*), Bamboo or reed storage structures (*Doli*), Wooden storage structures, Mud storage structures

(*Ghuma, Handi*), Underground storage structure (*Khani*), Bag storages and Masonry storage structures (Dash *et al.*, 1997). Though grain loss in these types of storage due to moisture, insects and rodents have been estimated to range between 3.5 and 8.2 % (RESC, 1994b), it is claimed that some of them offer special advantages like partial drying of high moisture grain in straw and bamboo storages and curing in underground storage. A study by He Yong and He Yong-sheng, (1996) in China revealed that the farmers' paddy is usually stored in wooden cabinet, stack by bamboo mat and stack on the ground. Of the three storage methods, loss with the wooden cabinet is the least, while loss of grain stack on the ground is the greatest.

Respiration of rice grains is taken into account when designing storage systems and since rice is a biological product, there may be some deterioration during storage even if it is stored at the 13.5 % 'safe' moisture content (Cogburn, 1985). The principal agents of rice deterioration during storage are fungi and insects and temperature and humidity influence their development. The limiting relative humidity is 65 % and corresponding equilibrium moisture content is 13 % (wet basis) for paddy. An aeration system for storage, if provided, has several advantages including equal storage temperature, thus avoiding the occurrence of hot spots; cooling of rice (depending on the weather) thus minimizing insect activity and mould growth; removal of odours from stored rice, and distribution of fumigants inside the stored product. Although there is no one optimum storage temperature, mould growth is inhibited below 21.1°C (70°F) (for rice at 13 moisture content, wet basis). Insect activity is considerably reduced below 15.6°C (60°F) (Luh, 1980).

2.3.5 Rice Parboiling

Parboiling of rice is an ancient tradition in most countries of the tropics; the original purpose was to loosen the hulls. However, in addition, there are other advantages relating to the increased nutritive value of parboiled rice. Water dissolves vitamins from the hull and bran and carries them to the endosperm. As in the case of wheat, the bran of rice contains much higher levels of vitamins than does the inner part of the grain. Rice hulls are also higher in vitamin content than the inner part of the grain.

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

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

The traditional process involves soaking rough rice overnight or longer in water at ambient temperature, followed by boiling or steaming the steeped rice at 100°C to gelatinise the starch, while the grain expands until the hull's lemma and palea start to separate (Gariboldi, 1984; Pillaiyar, 1988). The parboiled rice is then cooled and sun dried before storage or milling. Modern methods involve the use of a hot-water soak at 60°C (below the starch gelatinisation temperature) for a few hours to reduce the incidence of aflatoxin contamination during the soaking step. Vacuum infiltration to de-aerate the grain prior to pressure soaking is applied to obtain a good quality product, as is pressure boiling. The parboiled product has a cream to yellow colour depending on the intensity of heat treatment. Aged rice may give grayish parboiled rice, probably because it has a lower pH owing to the presence of free fatty acids.

Parboiling gelatinises the starch granules and hardens the endosperm, making it translucent. Chalky grains and those with chalky back, belly or core become completely translucent on parboiling; a white core or centre indicates incomplete parboiling of the grain. Parboiling results in inward diffusion of water-soluble vitamins, in addition to partial degradation of thiamine during heat treatment, except in heated-sand drying (Padua and Juliano, 1974). Parboiling does not decrease riboflavin content. Despite the degration of thiamine, parboiled milled rice has higher vitamin content then raw milled rice (Padua and Juliano, 1974).

In northern Ghana, parboiling has become a standard practice before rice is milled. 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 (Manful *et al.,* 1998; Yakubu, 1999). Variations in technique and subsequently the quality of the end product exist among the women of the three regions. No parboiling is done in the south of the country by small mill operators (Manful and Andoh, 1989).

2.3.6 Rice Milling

The purpose of rice milling is to remove the hulls and bran from the harvested, dried rough rice and to produce milled, polished or white rice with a minimum of breakage and impurities such as weed seeds in final product.

The meaning of the term milling varies appreciably, not only in the different industries in which the term is used, but also within the grain industry. For instance, milling of wheat refers to a grinding operation to produce a flour whereas in the rice industry, milling can refer to either the overall operations in a rice mill involving, cleaning, shelling, bran removal, size separation – or it can refer simply to the one operation of removal of the bran or outer layers from the brown rice to produce a whole grain white rice product (Luh, 1980; Kent and Evers, 1994).

2.3.6.1 Overview of the Rice Milling Sector in Ghana

Rice milling in Ghana can be grouped into three based on the scale of operation. These are household processing, small-medium scale custom milling and large-scale market oriented processing.

2.3.6.1.1 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 wooden mortar and pounded with a wooden pestle. 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 (Manful and Andoh, 1989; Yakubu, 1999). Hand pounding produces under-milled rice, still holding greater part of the bran layers, which is of greater nutritional value since it has high thiamine, protein, calcium and iron content.

An alternative method of rice hulling is to suspend a heavy wooden hammer beam horizontally on a fulcrum. The beam is then pressed by foot pressure on one end, and when this is removed, the outer end of the beam falls heavily down on the grains placed underneath it in a hollow in the ground, or in a strong wooden or stone bowel. The advantages of this over the hand pounding is that, it requires less effort and the output is greater (Mama, 1998).

Rice produced by manual pounding is usually for home consumption, with small surpluses traded mainly to neighbouring households. As such, it rarely enters the marketing chain.

2.3.6.1.2 Small-Medium Scale Rice Processing

Rice processing in Ghana is dominated by small to medium scale mills (Manful and Andoh, 1989). Much of the milling is done on custom basis – paddy is milled for a set price- and traders, mainly women, handle large quantities of rice. Mills are owned and operated by men. The small-medium scale rice mills are mainly stone hullers in the northern regions (Manful *et al.*, 1998; Yakubu, 1999) and rubber roller types in the southern sector of the country (Manful and Andoh, 1989). They have installed capacities up to 2 tons per hour.

2.3.6.1.2 Large-scale Rice Processing

Large-scale rice processing employs modern rice milling installations comprising 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. Manful *et al.* (1998) reports that there are five of such mills in Ghana, in the domain of parastatal and Government institutions. The two Satake mills in Tamale and Tono have a capacity of five tonnes/hour and one tonne/hour respectively. The mill in Tamale (Nasia mill) also has an automated parboiling facility with a capacity of four tonnes/hour.

2.3.6.2 Rice Milling Machinery and Operations

In some rice growing areas, rice milling is accomplished by pounding the rough rice in a wooden mortar and pestle followed by winnowing. At the other extreme are very modern methods where milling is accomplished in large, highly automated plants like the manifold operations being monitored from a central console (Tolson and Robe, 1977). Thus there is no typical mill. The modern processing of rice consists of essentially the same steps: Cleaning the incoming rough rice, shelling the rough rice, Milling to remove the bran from the brown rice, Grading the milled rice by length into whole grain and brokens, Mixing whole grains and brokens to meet specification of buyers, and Packaging.

2.4 FACTORS AFFECTING THE QUALITY OF MILLED RICE

2.4.1 Pre-milling Factors

2.4.1.1 Harvesting

To obtain high quality as well as high grain yields, rice must be harvested at the proper stage of maturity. If the crop is harvested too early (immature), breakage during milling is excessive due to the large quantity of thin, light and chalky kernels that are very fragile. If it is harvested too late, breakage during milling is excessive due to a phenomenon known as 'sun checking', which is the development of cracks in the individual kernels.

Several environmental and genetic factors influence rice milling performance. Daily fluctuations in relative humidity (RH) and temperature during rice maturity period and cultivar susceptibility to grain breakage are among the main factors (Kunze and Hall, 1967; Kunze and Prasad, 1978).These factors directly relate to the optimum moisture content of the grain at harvest (harvest moisture) at which level the head rice yield is maximum (Berrio and Cueva-Perez, 1989; Dilday, 1989; Seetanum and DeDetta, 1973). Above the optimum minimum harvest moisture, a higher percentage of immature kernels reduce milling quality, and below the optimum level, grain fissuring occurs resulting in lower milling yield.

Even though fissuring of rice grain and its subsequent effects on milling are well documented (Kunze and Hall, 1965, 1967; Kunze and Prasad, 1978), the results are inconsistent as they relate to the onset of fissuring among environments and cultivars. Subsequently, optimum harvest moisture recommendations vary considerably. McDonald (1967) reported that the highest moisture content observed in a fissured grain was 210 g/kg. Nagato (1964) indicated that kernels above 200 g/kg in moisture content do not crack by rewetting. Kunze and Hall (1965) indicated that rice with more than 150 or 160 g/kg moisture will not fissure when exposed to moisture adsorbing environment. Clearly, the sources of variation have been different environments and different cultivars. In another study by Jodari and Linscombe (1996), they found that considerable variability in weather patterns resulted in significantly different harvest moisture within cultivars.

Another harvesting factor which affects milling head yield is the mechanical action of the combine on the rice kernels. Matthews and Spadaro (1975) measured the effects of combining on rice breakage and head yield. They noted that combined harvested samples averaged over 5 percentage points more cracked and broken rough rice kernels than the hand-harvested samples. This difference in breakage carried through the subsequent milling operations. This observation was also made by Manful *et al.* (1998).

2.4.1.2 Drying

The drying conditions to which rice is subjected have a pronounced effect on breakage during milling. Jongkaewwattana, (1990) indicated that head yield may increase if drying is postponed for a day in order for the internal moisture gradient in the kernels, and the different moisture contents between the individual kernels to equilibrate. This may result in about 1% increase in head yield. Delaying the drying beyond 24 hours does not affect head yield. Delayed drying may however, not always improve overall quality. Sahays and Gangopadhyay (1985) have shown that delayed drying can cause heat burns or heat discoloration, yielding yellow rice kernels. Also, short grain Japanese varieties should be in the dryer within 4 hours of harvest (Mutters, 1998). Otherwise, undesirable odours develop which affects marketability negatively. Wasserman, (1960) reported that tempering rice after drying without cooling (40.5^{0}C) gave higher head yields than when the rice was cooled immediately after drying and tempered.

Imoudu and Olufayo (2000) studying Ekpoma rice in Nigeria, found that method of sun drying and moisture content of dried grains before milling significantly affected milling yield and percentage of broken grains. Parboiled rice dried on a concrete floor gave a higher yield percentage and lower proportion of broken grains than grains dried on mat.

2.4.1.3 Storage and Handling

Research has shown that rough rice storage history can affect head yield and cooking quality of rice (Villareal, *et al.*, 1976; Chratil, 1990; Hamaker *et al.*, 1993; Tamaki *et al.*, 1993). The conditions to which rice is subjected during transportation also have been shown to have an influence on the milling yield. Several investigators have studied the effect of storage time after drying on milling quality with varied results. Pominski *et al.* (1965), studying long and medium grain rice in the Southern United States, concluded that rice could be milled immediately after drying with no loss in head yield. He found milling yields did not significantly change over a 4-week storage period. Sorenson (1973) reported substantial increases in milling head yields (4-6 percentage points) for rice stored over 10-month period. This is in agreement with the work of Chouldhary (1970) who found that the tensile strength of rice increased during storage. He concluded that during storage, in a constant environment, the residual stresses which were induced by moisture gradients during drying may be gradually relieved resulting in a stress-free kernel which has a higher tensile strength and is less likely to break during milling.

The temperature and relative humidity during storage also affect rice quality. Yellowing occurs at high storage temperatures. Aibara *et al.* (1984) also mentioned that improper handling of fresh rice, either after harvest or during storage, could cause increased respiration and therefore loss of quality.

2.4.2 Milling Factors

The factors contributing to rice breakage during milling may be (1) those related to the properties of the rice grain itself or (2) those related to conditions under which the grain is milled. The properties of the grain itself at the time of milling is determined by both the inherent varietal properties of the rice kernel and by the conditions to which the rice is subjected during growing, harvesting, drying, storage, transportation and other processing. The conditions of milling affecting breakage are the rice temperature, moisture content during milling, the temperature and humidity of the milling environment, the degree of milling and operational conditions and mechanical settings of the machine (Luh, 1980).

During the shelling and milling (bran removal) operations, the rice kernels are subjected to mechanical forces in order to remove the husk and bran and produce white milled rice. Milling will cause the breakage of some kernels even in rice lots that have been harvested, dried and stored with extreme care. For lots, which have been subjected to poor treatment, milling may break every grain. The ideal milling operation is one in which the milling environment, rice properties and machine settings are controlled to minimise breakage (maximise head yield) while producing a rice with the desired degree of milling.

High humidity in the atmosphere during milling improves the yield of head rice. Increasing the moisture content of the grain to 14 to 16 % by steam vapour prior to milling also improves the head rice yield and its taste (Furugori, 1985), since 14 to 16 % is the critical moisture content range for crack susceptibility for most rice varieties (Srinivas and Bhashyam, 1985). Susceptible varieties readily crack below 16 % when exposed to higher humidity, but resistant varieties become susceptible at 14 %.

The presence of chalky regions in the endosperm (white belly or white core) contributes to grain breakage during milling. Presumably, a heterogeneous endosperm is more susceptible to cracking since a chalky mutant (Srinivas and Bhashyam, 1985) and waxy rice with uniform chalky endosperm (Khush and Juliano, 1985) give good milled rice.

2.4.3 Environmental Conditions Causing Milled Rice Kernel Breakage

Milled rice kernels have been shown to rapidly fissure and eventually break when exposed to certain air conditions (Siebenmorgen *et al.*, 1998). These conditions were identified as air temperature, relative humidity, kernel moisture content, and exposure duration and kernel temperature (in long grain varieties).

Milled rice kernels rapidly gain or lose moisture from the environment depending on the air temperature and relative humidity (RH) of the surrounding air, as well as the moisture content (MC) of the kernels (Kunze and Choudhary, 1972; Lu *et al.*, 1993). This integration into and out of the kernel causes tensile or compressive stresses to occur in the starch endosperm of the milled kernel (Stermer, 1968). Depending on the moisture gradient between the kernel and the equilibrium moisture content of the surrounding air, these stresses can cause kernels to fissure during post milling operations. This in turn can lead to kernel breakage and significant reduction in head rice yield (HRY).

In a work by Siebenmorgen (1998) on long grain rice varieties, relative humidity of the exposure air and MC of the milled rice at 13-14 % MC and RH range of 40-65 % were found to produce very little increase in rice breakage. Temperature of the exposure air was also shown to affect kernel damage with higher temperature levels causing more breakage at constant RH. Rice exposed immediately after milling showed lower breakage than samples exposed to the same air conditions a day later, indicating that milled rice kernel temperature influenced the amount of breakage, with thicker kernels incurring higher levels of damage than thinner ones.

In a similar study on medium-grain rice, Llyod *et al.*, (1999), reported that the least amount of breakage occurred in the RH range of 50-70 % RH at air temperature of 30°C for rice at 12.5 % MC. Also, the moisture content of the milled rice was a critical parameter in determining the extent of damage at a given environmental condition. High MC rice was more susceptible to damage at low exposure RH and low MC rice was more susceptible at high RH.

2.5. GROSS NUTRIENT COMPOSITION OF RICE FRACTIONS

The chemical composition of the rice grain varies considerably depending upon the genetic factor of plant variety and upon such environmental influences as location and season in which grown, degree of milling and conditions of storage.

Among the milling fractions of rice, the bran has the highest energy and protein content and the hull has the lowest (Table 4). Only the brown rice fraction is edible.

Abrasive or friction milling to remove the pericarp, seed coat, testa, aleurone layer and embryo to yield milled rice result in loss of fat, protein, crude and neutral; detergent fibre, ash, thiamine, riboflavin, niacin, and α-tocopherol. Available carbohydrates, mainly starch, are higher in milled rice than in brown rice. The gradients for the various nutrients are not identical as evidenced from analysis of successive milling fractions of brown rice (Barber, 1972). Dietary fibre is highest in the bran layer (and the hull) and lowest in milled rice. Density and bulk density are lowest in the hull, followed by the bran, and highest in milled rice because of the low oil content.

2.5.1 Vitamin Composition of the Rice Grain

The B vitamins are concentrated in the bran layers, as is α-tocopherol (vitamin E), (Table 5). The rice grain has no vitamin A, vitamin D or vitamin C (FAO, 1957). The locating gradient in the whole rice is steeper for thiamine than for riboflavin and niacin, resulting in a lower percent retention of thiamine in milled rice (Table 5). About 50 percent of total thiamine is in the scutellum and 80 to 85 percent of the niacin is in the pericarp plus aleurone layer (Histon and Shaw, 1954). The embryo accounts for more than 95 percent of total tocopherols (of which α-tocopherol account for one-third) and nearly one-third of the oil content of the rice grain (Gopala, 1984). By calculation, 65 percent of the thiamine of brown rice is in the bran, 13 percent in the polish and 22 percent in the milled rice fraction (Juliano and Bechtel, 1985). Corresponding values for riboflavin are 39 percent in the bran, 8 percent in the polish and 53 percent in the milled rice fraction. Niacin distribution is 54 percent in the bran, 13 percent in the polish and 33 percent in the milled rice fraction.

2.5.2 Ash Composition of the Rice Grain

The minerals (ash) are also concentrated in the outer layers of brown rice or in the bran fraction (Table 5). A major proportion (90 percent) of the phosphorus in the bran is phytin phosphorus. Potassium and magnesium are the principal salts of phytin. The ash distribution in brown rice is 51 percent in the bran, 10 percent of the germ, 10 percent in the polish and 28 percent in the milled rice fraction; iron, phosphorus and potassium show similar distribution (Resurreción *et al.,* 1979). However, some minerals show a relatively more even distribution in the grain: milled rice retained 63 percent of sodium, 74 percent of calcium and 83 percent of the Kjeldahl N content of brown rice (Juliano, 1985)

Table 4: Proximate composition of rough rice and its milling fractions at 14 percent moisture

Nutrient	Rough rice	Brown rice	Milled rice	Rice bran	Rice hull
Crude protein (g N × 5.95)	5.7-7.7	7.1-8.3	6.3-7.1	11.3-14.9	2.0-2.8
Crude fat (g)	1.5-2.3	1.6-2.8	0.3-0.5	15.0-19.7	0.3-0.8
Crude fibre (g)	7.2-10.4	0.6-1.0	0.2-0.5	7.0-11.4	34.5-45.9
Crude ash (g)	2.9-5.2	1.0-1.5	0.3-0.8	6.6-9.9	13.2-21.0
Available carbohydrates (g)	64-73	73-87	77-89	34-62	22-34
Neutral detergent fibre (g)	16.4-19.2	2.9-3.9	0.7-2.3	24-29	66-74
Energy content (kJ)	1580	1520-1610	1460-1560	670-1990	1110-1390
Density (g/ml)	1.17-1.23	1.31	1.44-1.46	1.16-1.29	0.67-0.74

Sources: Juliano, 1985b; Eggum *et al.*, 1982; Pendersen & Eggum, 1983.

Table 5: Vitamin and mineral content of rough rice and its milling fractions at 14 percent moisture

Vitamin/Mineral	Rough rice	Brown rice	Milled rice	Rice bran	Rice hull
Thiamine (mg)	0.26-.0.33	0.29-0.61	0.02-0.11	1.20-2.40	0.09-0.21
Riboflavin (mg)	0.06-0.11	0.04-0.14	0.02-0.06	0.18-0.43	0.05-0.07
Niacin (mg)	2.9-5.6	3.5-5.3	1.3-2.4	26.7-49.9	1.6-4.2
α-tocopherol (mg)	0.90-2.00	0.90-2.50	75-0.30	2.60-13.3	0
Calcium (g)	10-80	10-50	10-30	30-120	60-130
Phosphorus (g)	0.17-0.39	0.17-0.43	0.08-0.15	1.1-2.5	0.03-0.07
Phytin P (g)	0.18-0.21	0.13-0.27	0.02-0.07	0.9-2.2	0
Iron (mg)	1.4-6.0	0.2-5.2	0.2-2.8	8.6-43.0	3.9-9.5
Zinc (mg)	1.7-3.1	0.6-2.8	0.6-2.3	4.3-25.8	0.9-4.0

Sources: Juliano, 1985; 1982; Pendersen & Eggum, 1983.

2.5.3 Protein Content of the Rice Grain

The protein content of rice have been reported to range about 5% to more than 13% for milled rice and slightly higher for brown rice (Juliano, 1985b). Akuffo (1986) reported that the protein content of rice varieties obtained from the Ghanaian market ranged from 5.4 to 9.4 %. The variation in protein content is mainly due to varietal differences, planting date, fertiliser application and the environment.

Even though the protein content of polished rice is somewhat lower than that of wheat, maize and sorghum, the quality of the protein is considerably higher (Ihekoronye and Ngoddy, 1985). Lysine, the most limiting amino acid, constitutes about 4% of the protein of rice (Table 6), twice the level of wheat flour or dehulled maize. The lysine content of rice protein is 3.5 to 4%. Nevertheless, rice protein does not contain enough lysine, threonine or methionine. Consequently, for proper nutrition, supplementary foods such as grain legumes, meat and fish are added as part of the diet.

The amino acid content of the milling fractions is given in Table 6.

Table 6: Amino acid content of rough rice and its milling fractions at 14 percent moisture (g per 16 g N)

Amino acid	Rough rice	Brown rice	Milled rice	Rice bran	Rice hull
Histidine	1.5-2.8	2.3-2.5	2.2-2.6	2.7-3.3	1.6-2.0
Isoleucine	3.0-4.8	3.4-4.4	3.5-4.6	2.7-4.1	3.2-4.0
Leucine	6.9-8.8	7.9-8.5	8.0-8.2	6.9-7.6	8.0-8.2
Lysine +cysteine	3.2-4.7	3.7-4.1	3.2-4.0	4.8-5.4	3.8-5.4
Methionine + tyrosine	4.5-6.2	4.4-4.6	4.3-5.0	4.2-4.8	3.5-3.7
Phenylalanine	9.3-10.8	8.6-9.3	9.3-10.4	7.7-8.0	6.6-7.3
Threonine	3.0-4.5	3.7-3.8	3.5-3.7	3.8-4.2	4.2-5.0
Tryptophan	1.2-2.0	1.2-1.4	1.2-1.7	0.6-1.2	0.6

[a] Based on 5.8 g lysine per 16 g N as 100% (WHO, 1985).

Sources: Juliano, 1985b; Eggum *et al.*, 1982; Pendersen & Eggum, 1983

2.5.4. Carbohydrate Composition of the Rice Grain

Starch forms 90 % of milled rice, thus forming the major component of rice. Starch is a polymer of D-glucose linked α- (1, 4) and usually consists of an essentially linear fraction, amylose, and a branched fraction, amylopectin. Based on colorimetric starch-iodine colour absorption standards at 590 to 620nm, milled rice is classified as waxy (1 to 2 percent); very low amylose (2 to 12 percent), low amylose (12 to 20 percent), intermediate (20 to 25 percent), and high (25 to 33 percent), (Juliano, 1979; 1985b). Recent collaborative studies showed that the maximum true amylose content is 20% and that additional iodine binding is due to the long linear chains in amylopectin (Takeda *et al.,* 1987). Hence colorimetric amylose values are now termed 'apparent amylose content'.

The starch and amylose content available on the Ghanaian market ranges from 80.2 to 88.9 and 18.5 and 27.0% respectively (Akuffo. 1986).

2.6.5. Lipid Composition of the Rice Grain

The lipid or fat content of rice is mainly in the bran fraction (20 percent, dry basis), specifically as lipid bodies or spherosomes in the aleurone layer and bran; however, about 1.5 to 1.7 percent is present in milled rice, mainly as non-starch lipids extracted by ether, chloroform-methanol and cold water saturated butanol (Juliano and Goddard, 1986). Protein bodies, particularly the core, are rich in lipids (Choudhary and Juliano, 1980; Tanaka *et al.,* 1978). The major fatty acids of these lipids are linoleic, oleic, and palmitic acids (Hemavathy and Prabhaker, 1987; Taira *et al.*, 1988). Essential fatty acids in rice oil are about 29 to 42 % linoleic acid and 0.8 to 1.0 % linolenic acid (Jaiswal, 1983). The content of essential fatty acids may be increased with temperature during grain development, but at the expense of total oil content (Taira *et al.,* 1979).

3.0. MATERIALS AND METHODOLOGY

3.1. FIELD WORK

3.1.1. Survey Instruments and Study Area

Three sets of questionnaires (Appendices 1-3) were administered to rice farmers, rice millers and middlemen in the Greater Accra (Ashaiman, Asutsuare, and Dawhenya), Volta (Afife, Aveyime, Akpafu Odomi, Santrokofi Benua, Lolobi Kumasi and Hohoe) and Eastern (Akuse, Kpong, Kade, Akyem Abaam, Akyem Abodom and Abodom Bomso) regions of Ghana. The study areas were chosen based on convenience.

3.1.2. Sample Size

The sample size for farmers and middlemen were arrived at using the method of Kish (1995). A total of one hundred and twenty nine farmers and 52 middlemen were sampled from the Greater Accra, Volta and Eastern regions of Ghana. Forty eight farmers were sampled from the Greater Accra region, 40 from the Volta region and 41 from the Eastern region. Sample size calculations were based on the acreage and quantity of rice produced in the various regions per annum.

3.1.3. Sampling Techniques

Farmers were sampled using simple random sampling, middlemen by systematic random sampling and rice millers using purposeful sampling methods.

3.1.4 Rice Samples

Paddy or rough rice samples grown in 2001 were collected from both farmers and rice mills visited. Also, milled rice from the 2001 harvest was collected from middlemen at the various commercial mills visited for laboratory analysis. Varieties of rice collected included TOX 3107, TOX 3108, TOX 18447, Bouake 189, WITA 9, Perfumed rice, Emo korkor, Viwonor, and Adaesi.

Imported rice samples from Thailand (Diamond-perfumed), Viet Nam and the United States of America (US No. 5) were also obtained from a shop for comparison of the chemical properties with locally milled rice.

3.2 LABORATORY ANALYSIS

3.2.1 Sample Preparation

Rice samples were milled in hammer mill (Serial no. L625973, Christy and Norris Ltd, Chelsford, England) for determinations requiring the use of rice flour.

3.2.2 Physical Measurements

3.2.2.1 Analysis for Fractions

(1) Determination of foreign matter: 100g of the test sample was weighed and poured over a set of sieves (Laboratory test sieve, Retsch, D-5657, Germany) previously arranged in order of decreasing sieve size (4.75, 3.35, 2.00, 1.40, and 1.00 mm), with the largest on top. The samples were agitated thoroughly to strain out foreign matter at various levels.

The sieves were separated after straining and all foreign matter picked by hand or forceps from each of the sieves and added to what collected in the base pan. The total foreign matter was then weighed and expressed as a percentage of the test sample.

(2) Determination of fractions other than foreign matter: After the determination of foreign matter, the rice was spread evenly on a flat surface and thoroughly mixed. From the spread, 20g of the rice was taken from different positions by means of small scoops and weighed. The 20g rice was placed on an enamelled plate and with the help of a magnifying glass, various fractions in the order given in Table 7 below, were picked by hand, taking care that each fraction is accounted for only once. Each of the fractions was weighed on an analytical balance, capable of weighing to an accuracy of 5 mg, and the results calculated as a percentage of the total rice.

Table 7: Order of Separation of Fractions.

Order of Separation	Fractions
1	Insect damaged
2	Discoloured
3	Broken
4	Chalky
5	Red grains
6	Admixture
7	Insect(s) parts

Measurement of the various fractions above will enable the determination of the overall quality of samples to be compared with both Ghana and international rice quality standards.

3.2.2.2 Grain Size, Shape, Weight and Uniformity

- The length and width of 100 grains of each sample was measured with a venier calliper (Rabone Chesterman Ltd, England). Means of measurements were reported.
- Weight (size) was determined by taking the mean weight of a thousand (1000) kernel representative sample.
- The uniformity of rice is a measure of the coefficient of variation for each dimension of a representative sample

3.2.2.3 Bulk Density

This was done by measuring the volume of a 100g sample. Measurements were done in duplicates and averaged.

3.2.2.4 Colour

The colour of the milled rice samples was measured using a Hunter Lab Chromameter (CDM) model CR-300 (Minolta Camera Co. Ltd. Inc., Tokyo, Japan) using a porcelain plate with L=104.63, a=+ 0.31, and b= +4.63 as references. Results was expressed in Hunter L*a*b* values. Hunter L*, a* and b* values were used to calculate total colour differences (ΔE), defined as the square root of $L^2 + a^2 + b^2$. Three (3) random readings per sample were obtained and averaged.

3.2.3. Chemical Analysis

3.2.3.1 Moisture

The method described by the American Association of Cereal Chemists, method 44-15A (AACC, 1990) was used. Determinations were done in duplicates and means recorded.

3.2.3.2 Protein

The method described by the American Association of Cereal Chemists, method 44-10 (AACC, 1990) was used. Measurements were done in duplicates and means recorded. Protein content was calculated using nitrogen factor of 5.95.

3.2.3.3 Crude Fat determination

The American Association of Cereal Chemists, method 30-10 (AACC, 1990) were used. Determinations were done in duplicates and means recorded.

3.2.3.4 Mineral Analysis

Total ash was determined by the American Association of Cereal Chemists, method 08-01 (AACC, 1990). Two determinations per sample were done and results averaged.

Calcium, Magnesium, Zinc, Iron, Copper and Manganese were determined using the Atomic Absorption Spectrophotometer (model 3110, Perkin Elber; Perkin Elber Corporation, Norwalk, Connecticut) at wavelengths of 422.7, 285.2, 214.0, 248.3, 324.8, and 280.3 nm respectively. Zero point five grams each of Emo korkor, Adaesi, and Viwonor varieties were digested in 5 ml concentrated H_2SO_4. Hydrogen peroxide

(H_2O_2) was added during the digestion to obtain colourless digest. The digests were allowed to cool and then made up to 100 ml in a volumetric flask. The atomic absorption of the samples was then measured from a prepared calibration curve.

Phosphorus was determined using the colorimetric method and ascorbic acid as reductant. Zero point three grams each of the samples were digested in concentrated HCl: HNO3 (concentrated) (1:1) solution. The digests were allowed to cool and extract of 100 ml each was prepared.

Zero point eight seven eight grams (0.878 g) of potassium dihydrogen orthophosphate was dissolved in distilled water and diluted to a litre. Twenty-five ml was diluted to 1 litre to obtain the standard phosphate solution of 5μg P.

Two ml of the sample solution was measured into a 50 ml volumetric flask and the volume adjusted to 30 ml by adding distilled water. Two drops of P.nitrophenol and enough NH_3 solution was added to develop yellowish colour. Eight ml of ascorbic acid Stock was added to develop blue colour. The phosphorus content of the coloured solution was measured at 712 nm using an ATS 200M Flame Photometer (Milton Roy Spectronic 301; Bie and Berntsen AS, Switzerland) from the prepared calibration curve.

$$P_{(ppm)} = \frac{\text{reading x volume of extract}}{\text{Initial weight of sample taken x volume of aliquot}}$$

3.2.3.5 Degree of Milling

The method of Barber and Benedito de Barber (1976) was used.

3.2.4 Sensory Analysis

A sensory panel measured colour and Translucency visually. A multisample difference test (rating method) was used to determine in which way colour and translucency varies among the samples. A panel size of 36 was used.

3.2.5 Functional Properties

3.2.5.1 Amylose Content

Method described by Juliano, 1971 and Blakeney *et al,* (1994) was used in determining the amylose content of the rice samples.

3.2.5.2 Alkali spreading values

Method described by Webb (1985) was used in determining the alkali spreading values of the rice samples.

3.2.5.3 Water Uptake Capacity

The method described by Halick and Kelly (1959) was used.

3.2.5.4 Amylographic Cooked Paste Viscosity

The paste characteristics of 8% slurry (dry matter basis) of blended samples were determined using the Brabender Viscoamylograph (Brabender Instrument Inc., Duisburg, West Germany) equipped with a 700-cmg-sensitivity cartridge. The sample was weighed, mixed with water and made up to 500 ml in a volumetric flask. The suspension was heated from 25°C to 95°C at the rate of 1.5°C/min, held at this temperature for 30 minutes, and then cooled to 50°C at 1.5°C/minutes. The paste was then held at 50°C for 20 minutes.

Pasting temperature, peak viscosity, viscosity at 95°C, viscosity after 30 minutes at 95°C, viscosity at 50°C and viscosity at 50°C after 20 minutes were recorded.

3.3. Statistical Analysis

All statistical analysis and graphical presentations were done using Statgraphics (Graphics software system, STCC, Inc., USA) Statistical Package for Social Scientist (SPSS) and Freelance Graphics software. All results were significant at $p<0.05$ levels.

4.0 RESULTS AND DISCUSSIONS

4.1 FIELD SURVEY

4.1.1 4.1.1 General Discussion

4.1.1.1 Producer/ Farmer Practices - Issues of Quality Assurance

About 97 % of farmers harvest produce using knife, sickle, and/ or cutlass. About 94 % thresh rice manually and all farmers' sun dries their produce. The use of manual methods in the processing of rice in Ghana has significant effects on the annual rice production. Farmers could increase acreages of rice production if machinery were available for processing of rice. This would increase Ghana's self-sufficiency level. This undoubtedly, would reduce rice imports.

The single most prevalent problem in rice threshing was losses due to scattering and improper threshing using wooden box/ board. These losses inevitably, affect food security and the economies of the farmers and the country at large. If these losses could be prevented, more grains would be obtained and the self-sufficiency in rice would improve.

Cleaning of rice involves winnowing and sweeping through. These methods remove light materials but not heavier ones such as stones. Since straw, weed seeds, unfilled heads (blanks) and other extraneous materials provide focal points for heat damage, and interfere with operation of drying, their removal will speed up drying and reduce spoilage during storage.

The inability to monitor conditions of drying, mainly temperature and relative humidity most probably have adverse effects on kernels since kernels experience stresses during drying. When rice is dried too rapidly, the internal stresses would exceed the tensile strength resulting in checking or cracking of the rice kernel. These kernels are more susceptible to breakage during milling, resulting in reduced head rice yield (HRY).

Paddy, with its hard husk is easier to store than milled rice and shows less deterioration over longer periods. Paddy rice can remain in a relatively good condition much longer than milled rice, provided it is dried to 14 % moisture. Thus the practice of storing paddy rice would ensure better quality of rice than if milled rice were stored.

4.1.1.2 Processor/ Middlemen Practices - Issues of Quality Assurance

About 81 % of middlemen indicated that they dry paddy further before milling. Reasons given for drying paddy prior to milling showed that middlemen were knowledgeable about effects of high moisture content on milled rice yield and quality. This would have a positive effect on rice output.

The use of second hand sacks for packaging milled rice could have adverse effects on rice quality. Such sacks needs to be thoroughly disinfected by gassing, otherwise, they may introduce insects into newly milled rice thereby facilitating damage during storage.

The marketing system in the survey area was characterized by milling and selling (paddy and milled rice) on credit. This results in farmers being unable to produce rice in time the next planting season. This practice subsequently affects annual production of rice and affects Ghana's hope of attaining self-sufficiency in rice production. If the consumption of local rice can be promoted, it would ensure ready market for rice and hence reduce the tendency of buying on credit.

Most millers and middlemen store paddy in mill rooms. Rice stored in mill rooms is likely to gain and lose moisture due to temperature fluctuations. This could result in temperature- and moisture-induced tensile stresses, thereby increasing the susceptibility rice fissuring with subsequent reduction in head yields.

Mills in study area do not have precise maintenance schedule. Regular servicing of mills will promote milling efficiency; head yields as well as prolong the durability and reliability of mills.

The efficiency of dehulling and paddy separation could not be obtained from mills because they do not keep record of performance. The importance of record keeping cannot be underestimated. It provides useful information on activities of mills and enables millers to be more observant and accountable in use of mill.

The use of rubber rollers compared with use of steel hullers in milling of raw rice is advantageous. Rubber rollers are considered the best equipment raw rice as it does not encourage breakage during milling. The practice of not polishing white raw milled rice in Ghana has a positive influence on the higher mineral content of locally milled rice.

Most mills do not grade rice. The inability of mills to grade rice have effect on consumer preference and choice of imported rice over locally milled rice. If locally milled rice can be graded, different categories of consumers would patronize various grades and local rice could gain a greater market share.

4.1.2 Background Information on Rice Producers

A total of one hundred and twenty nine (129) farmers were involved in the study. Thirty seven point two percent (37.2%) of the farmers were from the Greater Accra Region, 31.0 % from the Volta region and 31.8 % from the Eastern Region. Table 8 shows the age-sex distribution of the farmers interviewed.

Table 8. Age-Sex Distribution of Farmers

Age (years)	Male (%)	Female (%)	Total
<20	3.9	-	3.9
20 – 29	11.6	0.8	12.4
30 – 39	20.9	6.2	27.1
40 –49	21.7	9.3	40.0
50 and above	21.7	3.9	35.6
Total	**79.8**	**20.2**	**100.0**

The age- sex distribution indicates that most (79.8 %) of the rice producers were male adults between the ages of 20 and 70 years. This is contrary to the report of FAO (1997) that in rural communities of sub-Saharan Africa, women are often the major producers and processors of food. This could be due to the laborious methods of rice production involving land clearing, planting, harvesting, threshing and drying, the involvement of a high number of adult males may have a positive effect on the annual production of rice.

Most of the rice farmers (89.6 %) (Figure. 1) have had some form of formal education. About sixty seven percent (66.7 %) had elementary education (Middle and Junior Secondary Schools). About 4 % had attained tertiary levels of education. As acknowledged by FAO (1997), improved education and literacy can influence the skills and knowledge needed for successful improved agricultural productivity as well as decisions regarding the expenditure of time and resources.

The main occupation of most (94.6%) of the rice farmers was rice production for marketing and consumption. A small proportion (5.4 %) of them were either tailors, mechanics, saw mill operators, palm wine tapers or students.

It was noted that 22.5 % of the farmers have been producing rice for up to 5 years. Also, 29.5 % have been producing rice in the past 6 to 10 years, 13.2 % in the past 11 to 15 years, 20.9 % in the past 16 to 20 years and 14.0 % for more than 20 years (Fig. 2). Generally, the longer the years in production, the more experienced the farmer. With only 14 % of respondents producing rice for the more than 20 years indicates that younger people are going into rice production. This may have a positive effect on rice production since the processes involved in rice production are laborious.

Fig 1. Educational level of rice farmers

A= None (9.5 %)

B= Elementary (66.7 %)

C= Secondary/ Commercial (19.4)

D= Tertiary (3.9%)

E= Non-formal (0.8 %)

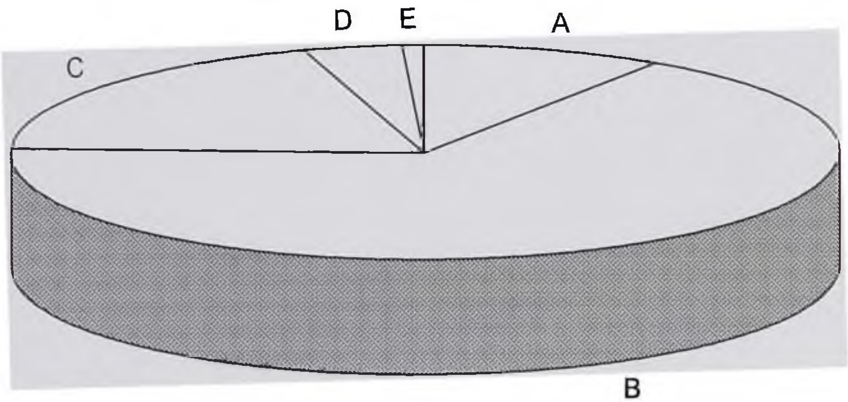
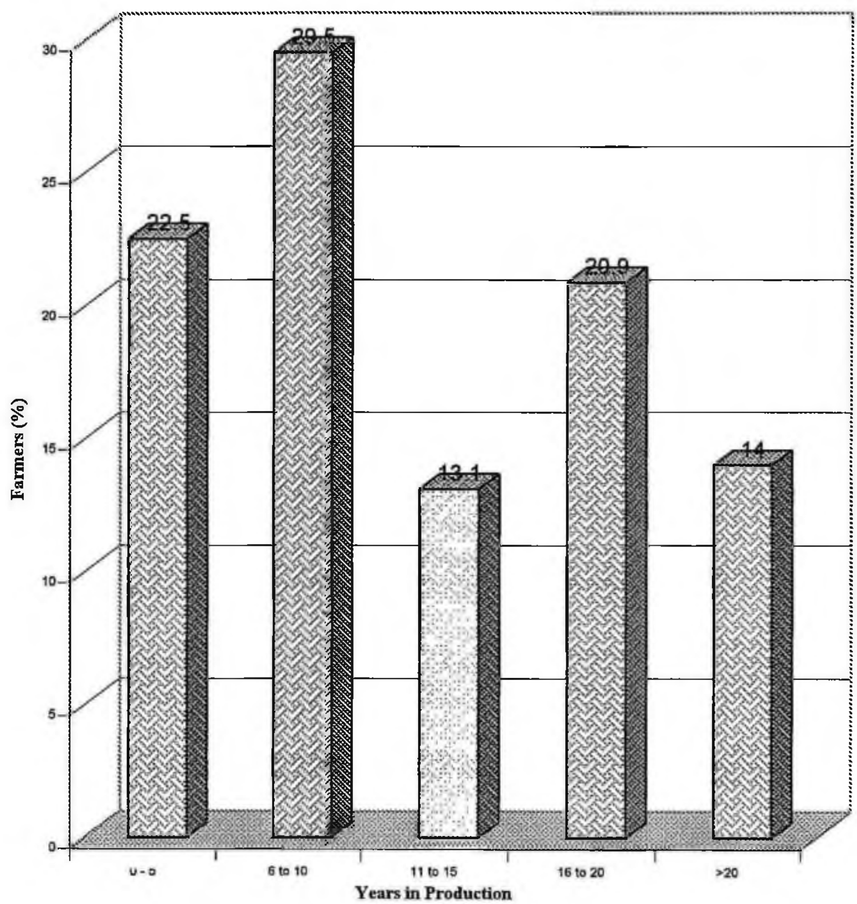

D
E
A
C
B

Fig.2. Distribution of Producers by Years in Rice Production


Farmers (%)
30
25
20
15
10
5
0
22.5
29.5
13.1
20.9
14
6 to 10
11 to 15
16 to 20
>20
Years in Production

4.1.3 Sources of Planting Material and Rice Varieties Grown

Forty nine point six percent (49.6 %) of the farmers obtain seed from either their own farms or from other farmers and from the various irrigation projects (Fig. 3). Other sources of seed include Ministry of Food and Agriculture, University of Ghana Agricultural Research Stations and Farmers' co-operatives.

Seed stand at the basis of the food production chain and is thus an essential input for most farmers. Seeds produced by farmers themselves can be of good quality but are more often than not infected by genetic deterioration or low germination capacity due to poor storage conditions, poor viability, presence of seed borne pathogens or a combination of these factors. These seed-borne diseases, if not immediately destructive, killing the embryonic seeds or seedlings at an early stage, their longer term damage can be much greater when their symptoms become apparent at a later stage of the plant life. This will then mean that the farmer can be faced with disease problems for which he will need expensive chemicals. The provision of seeds by extension officers and the University of Ghana Agricultural Stations will be more appropriate since seeds are more likely to be tested and better stored, hence maintaining viability and quality of seeds. Proper storage or packing is therefore a problem the farmer needs to solve when there is dependence on farm produced seeds.

The distribution of farmers by varieties of rice grown (Table 9) shows that Bouake 189 is the main variety of rice being cultivated in the Greater Accra region at the time of the survey (41.2 %). In the Volta region, TOX 3107 was the major variety grown (22.8 %) while Emo korkor was the most dominant variety in the Eastern region (58.2 %). Volta region however, recorded the production of a higher number of varieties. This is probably because there were not many farmers' associations hence each farmer decides which variety to grow. The people of the Kwaebibirem district of the Eastern region indicated that they preferred to grow Emo korkor due to their farming systems – mostly upland and lowland rain-fed. However, 86 % of the producers indicated that there were some varieties of rice they will usually not cultivate due to various reasons.

Table 9. Distribution of Farmers by Varieties of Rice Grown

Variety	Frequency			Percentage		
	G. Accra	Volta	Eastern	G. Accra	Volta	Eastern
TOX 3107	19	18	6	14.7	14.0	4.6
TOX 3108	2	13	-	1.6	10.1	0.0
TOX 18447	2	10	-	1.6	7.8	0.0
Bouake 189	28	8	8	21.7	6.2	6.2
Perfumed	9	5	-	7.0	3.8	0.0
ITA 406	5	-	-	3.8	0.0	0.0
Emo korkor	-	-	32	0.0	0.0	24.8
Emo fita			9	0.0	0.0	7.0
Viwonor	-	11		0.0	8.5	0.0
Adaesi		7	-	0.0	5.4	0.0
Total	**65**	**72**	**55**	**50.4**	**55.8**	**42.6**

Fig. 3. Rice Seed Sources for Planting

A= Farmers (49.6 %)

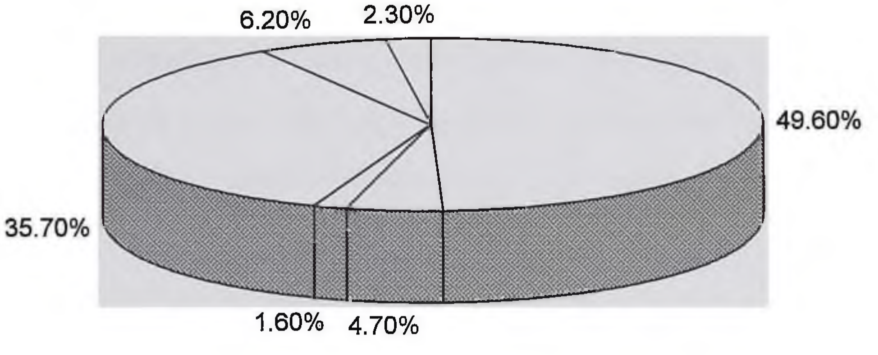
B= Ministry of Food and Agriculture/ Extension officers (4.7 %)

C= University of Ghana Agricultural Research Stations (1.6 %)

D= Irrigation Projects (IDA, KIP, Kpong farms, SSIAPP) (35.7 %)

E= Farmers' Co-operatives (6.2 %)

F= Middlemen/ stores (2.3 %)


6.20%
2.30%
49.60%
35.70%
1.60%
4.70%

Marketing problems were the main factors considered by farmers in taking decision regarding the variety of rice to grow (Table 10). The citing of the refusal of middlemen and traders to purchase certain varieties of rice confirms that the Ghanaian consumer has developed taste for superior quality rice hence will only buy rice of a certain desired quality.

About 12 % of farmers indicated that TOX 3107 have poor milling quality and is therefore not a preferred variety for cultivation. The high susceptibility of TOX 3107 to breakage could be due to its length-to-width ratio. Long-grain varieties are more susceptible to breakage than the short grain varieties. Sarker and Farouk (1989) noted that the thickness of grains does not always increase proportionately with the length of grains. This could be a contributing factor as TOX 3107 is an extra long grain and very slender.

The cultivation of TOX 3107 as the main variety in the Volta region even though TOX 3107 has been reported to have poor milling quality could be attributed to its length and market value as it has been reported to be readily patronised due to its slenderness. TOX 3107 is also said to cook dry and fluffy.

Planting Time

Most farmers plant rice in the rainy season. About 44 % indicated that they plant their seeds between January and March, 42.6 % between April and June, 7.8 % plant seeds between July and August and only 2.3 % between October and December. Three percent of the farmers indicated that they plant rice any time of the year. This implies that

Table 10. **Reasons for not growing Some Varieties of Rice**

Variety	Reason	Frequency (Percent)		
		G. Accra	Volta	Eastern
TOX 18447	Hard to thresh	2 (1.6)	4 (3.2)	-
TOX 18447	Poor yield on farm	-	1 (0.8)	-
TOX 3107	Poor milling quality and output	10 (7.8)	-	5 (3.9)
TOX 3107	Long growing period	2 (1.6)	-	-
TOX 3108	Hard to thresh	2 (1.6)	-	-
Emo korkor	Poor yield than Emo korkor	-	-	9 (7.0)
Emo fita	Plant very tall, wind scatters grains	-	-	3 ((2.4)
Various Varieties	Marketing problems	11 (8.5)	8 (6.2)	14 (10.9)
Total		**37 (28.7)**	**13 (10.1)**	**31 (24.0)**

though most of the farmers have irrigated farms, they depend on rainwater to fill the dams for effective irrigation of fields. Regular rain pattern and climatic conditions will therefore be essential for crop cultivation and growth.

Farming Systems

Sixty six point seven percent of the farmers had irrigated farms, 16.3 % cultivate on upland, and 3.9 % had farms on inland valley whilst 13.2 % have lowland rain-fed farms (Fig. 4). Since high yields are obtained from the irrigated ecology, (3.5 to 7 tonnes/Ha) (SRID, 2001) and the irrigated ecology has potential for higher cropping intensity, and insurance against weather induced stress, due to the ability to control and manage water, the higher percentage of farmers involved in this farming type may indicate higher yields in the study area. It will therefore, also be expected that quality of rice obtained from the study area should not be significantly affected by moisture during the growing period.

The other farming ecologies depend mainly on rainfall. Lowland rain-fed ecology has a more favourable crop-moisture endowment than the rain-fed upland zone. Hence rice crop obtains much of its water requirements from raised water table after floodwaters recede. Thus, the cultivation of rice in ecologies rather than irrigated will be dependent mainly on rainfall pattern, which will be essential for successful crop growth and yields.

4.1.4. Rice Pre-Harvest Technologies

4.1.4.1 Pre-harvesting factors

The pre-harvest quality of paddy rice influences post-harvest quality. Rice is usually grown in swampy lands hence the farm is flooded during the growing period of rice. Sixty four point three percent of farmers indicated that they drain the field before harvesting the rice. The drainage process involves opening outlets or pipes (irrigation farms) to allow the water to flow out of the field. However, the duration before harvesting after the drainage outlets have been opened differed for all the farmers. Forty percent indicated that they harvest the paddy rice 1 to 2 weeks after opening the drainage outlets. Fourteen percent of them harvest the paddy less than a week after opening the drainage outlets while 11.7 % harvest their paddy after two weeks of drainage (Table 11).

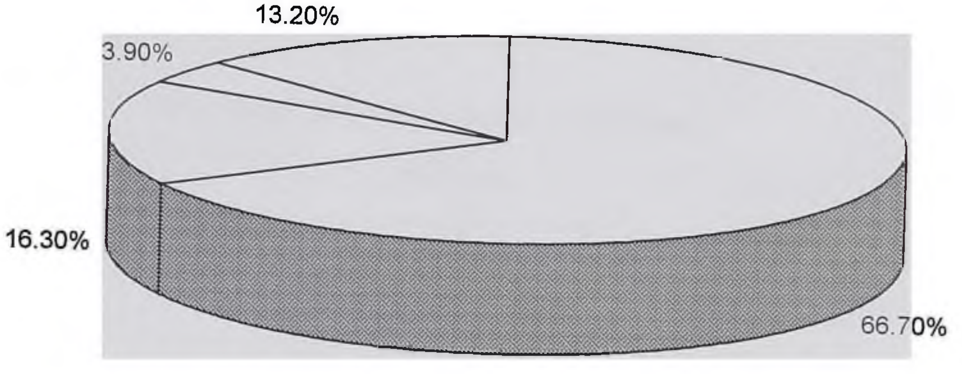
Fig.4. Distribution of Farmers By Farming Type Engaged In

A= Irrigation (66.7 %)

B= Upland (16.3 %)

C= Inland Valley (3.9 %)

D= Lowland Rain-fed (13.2 %)



13.20%
3.90%
16.30%
66.70%

Luh (1980) indicated that the precise timing for draining each field is determined by the drooping of the heads (panicles), which indicates the size and number of rice kernels. This is usually about 2 to 3 weeks before harvest. However, only 10.1 % of the farmers harvest paddy 2 to 3 weeks after drainage.

When asked what they consider before deciding to drain the field, most of those who drain the field (66.7 %) indicated that changes in colour to yellowish or ripening of the panicles are considered (Table 12).

Table 11. Period Elapse Before Harvest After Field Drainage

Duration	Frequency	Percent
< 1 week	18	14
1-2 weeks	51	39.5
2-3 weeks	13	10.1
> 4 weeks	2	1.6
Not applicable	45	34.9
Total	**129**	**100.0**

Twenty five percent follow a cropping program designed by the irrigation projects hence calculate the number of days after planting to decide when to drain the field while 3.6 % look out for the drooping of heads of panicles. When asked to describe the drainage process, all the farmers said they open the drainage outlets. This could be an indication that flow of water is not controlled hence, most of the water on the field could run off easily and quickly if the field is sloppy. Slow draining however, helps to reduce lodging and the stem of the rice plant is stronger if it hardens slowly as it dries (Spadaro *et al.*, 1980).

The factors considered by farmers to harvest are shown in Table 13. Most of the farmers look at the change in colour of panicles in deciding to harvest. Thirteen percent of them follow cropping programs, 3.9 % consider the bending or drooping of panicles, 3.9 % look at both the ripeness of panicles and the degree of dryness of the soil surface while 1.6 % look at only the drainage of the soil.

Table 12. Factors considered by rice farmers to drain field

Factor	**Frequency**	**Percent**
Change in colour of panicles to yellowish/ripening of field	86	66.7
Follow cropping program	32	25.0
Drooping of panicles	5	3.6
When 70-75% of field is ripe/maturity level	6	4.7
Total	**129**	**100.0**

The 1.6 % explained that at the time of drainage, the kernels had reached maturity hence they pay attention to only the level of drainage.

Table 13. Factors Used By Farmers to Decide to Harvest Paddy Rice

Factor	Frequency	Percent
Change in colour of panicles to yellow	100	77.5
Calculate number of days after planting	17	13.2
Level of field drainage	2	1.6
Drooping of panicles	5	3.9
Ripeness of panicles / drainage level of field	5	3.9
Total	**129**	**100.0**

4.1.5. Rice Post-harvest Technologies

4.1.5.1.Harvesting Methods

Most of the farmers harvest their produce manually (96.9 %) (Table 14). Only 3.1 % use mechanized harvesting. About 50 % use sickle in harvesting while 43.4 % use knife and/or cutlass.

When asked whether in their opinion, the method and equipment used in harvesting have any effect on the milling yield and quality, only 6.2 % of the producers responded in the affirmative. Ninety three percent did not think the method and equipment used in harvesting have effect on the output of milled rice while 0.8 % said they did not know or could not tell. However, the mechanical action of the combine is known to affect milling head yield.

Table 14. Tools Used By Farmers In Harvesting

Tool	Frequency	Percent
Combine	2	1.6
Sickle	65	50.4
Knife/cutlass	56	43.4
Kubota harvester/reaper	1	0.8
Hand	1	0.8
Combine + sickle	4	3.1
Total	**129**	**100.0**

Matthews and Spadaro (1975) measured the effect of combining on rice breakage and head yield and noted that, combine harvested samples averaged over 5 percentage points more cracked and broken rough rice kernels than hand harvested samples. They also noted that the difference in breakage carried out through the subsequent milling operations. The ignorance of farmers on the effect of harvesting method and equipment on rice quality could have adverse effect on milled rice quality, as farmers may not pay attention to the use of method and equipment. However, only 4 % of the respondents use any form of mechanized harvesting, including combine harvesting.

The ignorance of the farmers on the effect of harvesting method and equipment on milling output could be attributed to the fact that most of them have been using the same harvesting methods year after year and hence did not have the privilege of comparing methods and equipment. It could also be because they have not had any formal education on rice farming hence do not know the effect of these methods and equipment. The effect of harvesting methods and equipment mentioned by the 6.2 % of respondents were that hand harvesting results in high head yield and affects the brightness or translucency of milled rice.

4.1.5.2.Rice Threshing

Threshing is the separation of the rice grain from the panicles but not removing the husk. From the survey, 74.4 % of the producers thresh their paddy manually (Fig.5). Five point four percent indicated they use combine harvesters in threshing while 20.2 % use either a Kubota thresher or another form of mechanized threshing. Thirty eight percent of the farmers thresh paddy by beating bunches of panicles against a wooden threshing box or board, 28.7 % hit the bunches of panicles against concrete slabs or stones (Fig. 6) while 5.4 % and 2.3 % beat panicles packed on tarpaulin and concrete floor respectively with sticks.

Thirty six percent (36 %) of the farmers had no problem with the methods of threshing used. Forty six point one percent (46.1 %) of farmers said losses occur during threshing either due to scattering of grains or incomplete threshing, 7.8 % complained of breakage and partial polishing of kernels during threshing whilst 5.4 % complained of contamination with stones, dirt and other foreign material. Nine point three percent (9.3 %) said the methods of threshing they use are labour intensive and usually not readily available. The breakdown of the tools with the accompanied problems is presented in Table 15.

It will be noted that the single most prevalent problem is losses due to scattering and improper threshing using wooden box/board. Since threshing is done on the farm or at home, grains scattered cannot be collected as some get buried, while others scatter too far off to be noticed. These losses inevitably, affect food security and the economies of the farmers and the country at large. If these losses could be prevented, more grains would be obtained and the self-sufficiency level of rice in Ghana world be improved. Also, a total of 7.8 % of respondents complaining of kernel breakage and partial polishing during threshing is high considering that, threshing is the beginning of the post-harvest processes. This is probably carried out through subsequent operations in the milling system. Breakage and partial polishing of rice grains using sticks is most probably due to the stress induced in the kernels by the force of impact on hitting the paddy. None of the problems could however be quantified.

Fig. 5. Distribution of Tools Used by Farmers In Rice Threshing

A = Combine Harvester (5.4 %)

B = Wooden threshing box/board (38.0 %)

C = Concrete slabs or stones (28.7 %)

D = Sticks on tarpaulin (5.4 %)

E = Sticks on concrete floor (2.3 %)

F = Threshing machine /Kubota thresher (20.2 %)

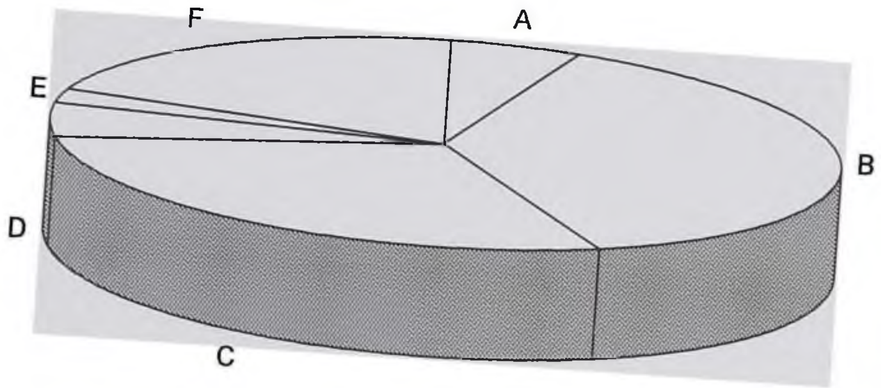

F
A
E
B
D
C

Fig. 6. Rice Threshing by Hitting Panicles against Concrete Slabs

Table 15. Problems with Threshing Tools

Problem	Tool	Frequency	Percent
Losses due to scattering/improper threshing	Threshing box/board	25	19.4
	Concrete slabs/stones	21	16.3
	Kubota thresher	7	5.4
	Sticks on tarpaulin	2	1.6
	Sticks on concrete floor	2	1.6
Breakage/partial polishing of kernels	Threshing box/board	1	0.8
	Kubota thresher	7	5.4
	Sticks on tarpaulin	6	4.6
	Sticks on concrete floor	3	2.3
Contamination with stones, dirt and other foreign material	Kubota thresher	4	3.1
	Concrete slabs/stones	1	0.8
	Sticks on concrete floor	2	1.6
	Threshing box/board	1	0.8
Labour intensive and labour not readily available	Threshing box/board	7	5.4
	Concrete slabs/stones	6	4.6
	Sticks on tarpaulin	4	3.1

4.1.5.3.Paddy Rice Cleaning

Freshly threshed rice may spoil rapidly when exposed to high temperature, high moisture content, mould and foreign matter. Promptly cleaning to remove all straw, chaff joints and weed parts will speed drying and lessen danger of spoilage and insect damage and hence improve milled rice quality.

It was noted that 90.7 % of farmers indicated that they clean or remove impurities from the paddy always while 6.2 % remove foreign matter from paddy sometimes. Three point one percent however never pass the rice through any form of cleaning. It was noted that, most of the farmers (53.5 %) clean the paddy by winnowing- thus tossing the paddy into the air and allowing the wind to carry off the chaff. However, in winnowing, higher density foreign materials such as stones cannot be removed. Some of the farmers (32.6 %) combine winnowing with sweeping through the grains during drying (Fig. 7a), while 1.6 % cleans only by sweeping through during drying. A small proportion (3.9 %) of the farmers use a special type of sieve (Fig. 7c) to remove high-density materials such as stones, in combination with winnowing, which removes lighter materials. Three percent pick foreign materials by hand, while 2.3 % of farmers clean paddy by mechanical aspiration using the blower (Fig. 7b).

It should be noted that most of the cleaning methods employed remove lighter or less dense materials while the heavier ones such stones cannot be removed by such methods as winnowing and sweeping. Thus there is the likelihood of stones, metals and other high-density materials remaining in the paddy rice. These can damage sieves in the mill when paddy is processed in mill without destoners and gravity separators. Since straw, weed seeds, unfilled heads (blanks) and other extraneous materials provide focal points for heat damage and interferes with operation of drying, the removal of these foreign materials during drying will speed up drying and reduce spoilage during storage.

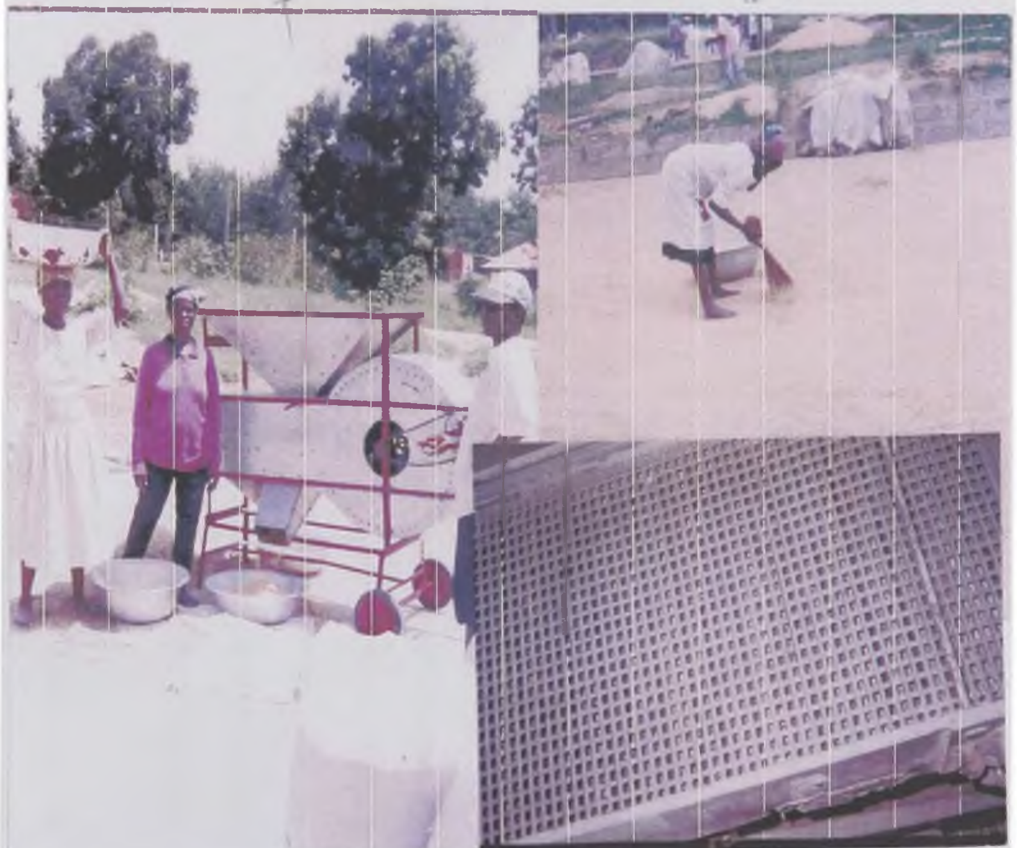
Fig. 7. Cleaning of Paddy Rice to Remove Extraneous Matter

A: by sweeping through kernels during drying to remove chaff

B: using the blower to remove light density materials

C: using the sieve to remove high-density materials

B A



C

4.1.5.4.Paddy Rice Drying

After threshing, the grains are usually dried further to supplement the preliminary field curing. When this is properly done, paddy with good keeping quality and maximum head rice yields at milling is obtained. Drying also reduce the moisture content of grains from about 24-26 % to 12-14 % for either storage or milling.

Most (99.2 %) of the farmers said they dry their paddy before milling. Most of the farmers' use drying floors made of concrete. All the farmers depend on the sun-energy for drying and all said they stir the paddy during drying. Stirring periodically to minimize moisture gradients within the bulk of the rice is done using rakes (Fig. 8), sticks and by walking through. Stirring facilitates uniform drying. Concrete drying floors may retain heat and become too hot, causing the paddy to dry too quickly and to suncrack. Too rapid drying may also cause 'case hardening'; the moisture within the grain cannot through a hardened surface, making the grains more susceptible to fissuring during milling.

Sixty six percent dry the paddy immediately after harvest, 11.6 % dry their paddy by the third day after harvest, while 7.8 % and 14 % dry the paddy 1-6 months and 6-12 months respectively after harvest. The 21.8% of the farmers who dry the paddy more than a month after harvest are farmers from the Kwaebibirem district of the Eastern region who said they harvest the panicles when the rice is well dried and only thresh when ready to mill, which is usually more than a month after harvest. A study by Jongkaewwattana (1990) indicates that head rice may increase by 1 % if drying is

Fig. 8. Stirring Paddy Rice during Drying Using the Rake

postponed for a day for the internal moisture gradient in the kernels, and the different moisture contents between the individual kernels to equilibrate. However, Sahays and Gangopadhyay (1985) have shown that delayed drying can cause heat burns or heat discoloration. Delayed drying also causes deterioration of total quality (He Yong and He Yong-sheng, 1996). Thus there is the possibility of reduction in total quality of rice grown in the Kwaebibirem district as rice may be over dried on the field or could have moisture level that will facilitate spoilage in storage. High moisture in grains during storage could also promote fungal activity. Delayed drying may also result in the development of undesirable odours in rice, which may affect marketability negatively (Mutters, 1998). Immediate drying of paddy after harvest will reduce mould attack and maintain total quality.

Since rice is sun dried, farmers are unable to control the temperature and humidity of the drying environment. Also the moisture content of the paddy cannot be objectively measured hence the farmers depend on their experiences to determine whether the kernels are dried enough to be either stored or milled.

The inability to monitor conditions of drying, mainly temperature and relative humidity, most probably have adverse effects on kernels since kernels may experience stresses during drying. The magnitude of these stresses depends upon moisture and temperature gradients within the rice kernel. When rice is dried too rapidly, the internal stresses will exceed the tensile strength resulting in checking or cracking of the rice kernel (Chouldhary, 1970). These checked kernels are more susceptible to breaking during milling, resulting in reduced head yield.

In addition, 80.8 % of middlemen indicated that they dry the paddy further before milling. Reasons given by middlemen for drying the paddy are shown in Table 16. Forty six percent (46 %) indicated that they dry the paddy to prevent breakage during milling since the kernels become wet or damp during storage. Some (13.5 %) of the middlemen said the kernels usually contain too much moisture, sometimes due to inadequate drying by farmers hence they dry the grains further. Few (11.5 %) specifically said they dry the paddy before milling so as to obtain higher head and total milled rice yields. Thus, most (67.4 %) of the middlemen are aware of the effect of moisture content of kernels on the final milling yield and output.

Table 16. Reasons given by Middlemen for Drying Paddy before Milling

Reason	Frequency	Percent
To prevent breakage during milling	24	46.2
To dry further	7	13.5
To obtain high head and total milled rice yield	6	11.5
To produce well milled rice with good appearance	3	5.8
To produce high head rice yield and good appearance	2	3.8
Rice goods dry and fluffy when well dried prior to milling	1	1.9
Not applicable	9	17.8
Total	**52**	**100.0**

Since middlemen mill rice mainly, they were asked how they determine that the moisture content of the kernels is optimum for milling. The middlemen indicated various means by which they tell the moisture content of the grains (Table 17). Most of them (69.2 %) break the kernels with the teeth. When the kernels break into two without scattering, then the moisture content is appropriate for milling. Some (9.6 %) gently rub the kernels between either two fingers or under the foot. When the husk comes off easily, then the kernels are well dried. Only 1.9 % use moisture meter in determining the moisture content of the paddy prior to milling. The 17.3 % of respondents whose responses were not applicable were those in the Kwaebibirem district, where mainly farmers do the milling.

The inability of farmers and middlemen to objectively measure the moisture content of rice could have adverse effect on rice quality as moisture content has a marked influence on several facets of rice quality. Rice will keep longer if the moisture content is maintained at a uniformly low level. Also, head rice yield is increased when moisture content is in the range of 12-14 %.

Table 17. Methods used to determine Appropriateness of Paddy Moisture Content for Milling

Method	Frequency	Percent
Teeth test	36	69.2
Rubbing test (finger and foot)	5	9.6
Press between stones	1	1.9
Moisture tester	1	1.9
Not applicable	9	17.3
Total	**52**	**100.0**

4.1.5.5. Storage of Rice

4.1.5.5.1. Storage of Paddy Rice

Paddy rice can either be milled immediately after drying or stored until needed. The conditions to which rice is subjected during storage have an influence on the milling head yield (Tanaki *et al.*, 1993).

Most (84.5 %) of farmers indicated that they store paddy rice before milling whilst he remaining 15.5 % either mill the rice for marketing immediately after drying or sell them off to middlemen. Sixty point five percent of all the farmers pack the paddy rice in sacks while 20 % of the farmers store panicles in traditional cribs or barns. Of those who store the rice before milling, 82.9 % store them at room temperature in living rooms, and warehouses made of either concrete or wood while 2.3 % either store the paddy at room temperature or outside (open air), and cover it with either tarpaulin or polyethylene material. Ninety five percent (95 %) of the farmers indicated that they keep each variety of rice separate during storage. Farmers store paddy rice for various durations (Table 18) before either selling off or milling.

Table 18. Duration of Paddy storage by Farmers

Duration	Frequency	Percent
< 2 weeks	4	3.1
2 weeks – 1 month	6	4.7
1 – 5 months	48	37.2
> 5 months	52	40.3
Not applicable	20	14.7
Total	**129**	**100.0**

Several investigators have studied the effects of storage time after drying on milling with varied results. Pominski *et al.* (1965), studying long grain and medium grain rice in Southern United States, concluded that rice could be milled immediately after drying with no loss in head yield. He found milling head yields did not significantly change over a 4-week storage period. The data of Wasserman (1961) on short grain rice also showed higher head yields immediately after drying. Sorenson (1973) reported substantial increases in milling head yields (4-6 % points) for rice stored over a 10-month period. This is in agreement with the work of Chouldhary (1970) who found out that the tensile strength of rice increased during storage thereby resulting in rice that is less likely to break during milling.

Neal (1970) studied the milling of rice that was harvested and stored without drying for various periods of time at various moisture levels. He reported that the undried rice declined in grade before there was any decline in milling yields.

Most (63.5 %) of middlemen store paddy for various durations (Table 19) before milling. Some (19.2 %) mill the paddy without prior storage. It was noted that most (61.8 %) of middlemen store paddy rice so as to await higher prices. Twenty nine percent store paddy until there is demand for it by a customer while 2.9 % said storing paddy rice facilitates ageing and higher head rice yield. About 6 % however store rice for the lean season when paddy is not available to be purchased.

Paddy, with its hard husk is easier to store than milled rice and shows less deterioration over longer periods. In the same storage conditions, milled rice, with the best known store management and disinfection measures, is at considerable risk after six months storage (Abbott *et al.*, 1972). Thus paddy rice can remain in a relatively good condition much longer than milled rice, provided it is dried to 14 % moisture. Storage of rice prior to milling will also age rice and produce more fluffy rice upon cooking. This is important because rice is mostly consumed immediately after milling in the study area.

Middlemen store paddy rice in sacks heaped on concrete floor in a room (25 %) in sacks packed on pallets in a living room or warehouse (34.6 %) and in sacks kept in the milling room. Storage of paddy rice on concrete floor could result in moisture transfer between the floor and paddy, thereby inducing stress in the paddy. Stress induced grains are more susceptible to breakage during milling. Paddy stored in milled room could also experience temperature-induced stress due to fluctuations in temperature of milled room. This could also affect head yields and hence, total quality of milled rice.

Table 19. Duration of Paddy Storage by Middlemen

Duration	Frequency	Percent
< 2 weeks	1	1.9
2 weeks – 3 months	13	25.0
3 – 6 months	13	25.0
6 – 12 months	7	13.5
Not applicable	18	34.6
Total	**52**	**100.0**

4.1.5.5.2. Storage of Milled Rice

Only 17.3 % of middlemen store milled rice. Out of these, 55.6 percent store milled rice to await higher prices, 22.2 % to await market or until there is demand for rice while the other 22.2 % store milled rice so as to dry it further. Forty four percent store the milled rice in sacks packed on pallet in mill room, 44.4 % in sacks heaped on pallets in living room while the remaining 11.2 % keep the milled rice in sacks kept on concrete floors.

Storage of milled rice age rice further and hence produces drier and fluffier rice upon cooking. However, if milled rice is not kept well, it could fissure and eventually break. Factors that could affect fissuring include air temperature, relative humidity, kernel moisture content, exposure duration and kernel temperature (Siebenmorgen *et al.*, 1998). Kernels could also gain or lose moisture from the environment (Lu *et al.*, 1993) resulting in tensile or compressive stresses in the starch endosperm of the milled kernel (Stermer, 1968), especially kernels stored on concrete floors. This in turn can lead to kernel breakage and significant reduction in head rice yields (HRY).

4.1.6. Problems faced in rice Production

The survey also looked at the problems faced by farmers in rice production. Forty-four farmers (34.1 %) mentioned high cost of inputs as their main problem (Table 20), 30 of them (23.3 %) indicated that rice farming is labour intensive and require the attention of the farmer all the time hence time consuming. Financial constraints and high interest on loan was the third most prevalent problem (19.4 %) followed by insufficient /lack of machinery (15.5%). It should be noted that the labour intensity of the cultivation and processing of rice is mainly due to lack of machinery, since most of the processes are carried out manually. Thus the result is 96.9 % of farmers harvest by sickle, knife or cutlass, 74.4 % threshing manually and all the farmers' sun drying their produce.

The use of manual methods in the processing of rice in Ghana has significant effects on the annual rice production. Farmers could increase acreage of rice production if machinery were available for processing of rice and thereby increase Ghana's rice self-sufficiency level. This, undoubtedly, will reduce rice imports.

The other problems mentioned include rodent attack, high cost of hiring facilities, irregular rainfall pattern or weather fluctuations as well as quantitative losses of rice at each processing step.

Table 20. Problems faced by farmers in rice production by region

Problem	Frequency			Total
	G. Accra	Volta	Eastern	
Insufficient/ lack of machinery	5	13	2	20
Financial constraints/ high interest rates	10	9	6	25
High cost of inputs	5	15	22	42
Labour intensive/ Time consuming	4	6	20	30
Weather fluctuations	1	2	6	9
Pest/ rodent attack	4	3	7	14
High cost of hiring facilities	1	2	9	12
Quantitative losses	1	3	3	7
Total	**31**	**53**	**75**	**159**

4.1.7. Rice Marketing and Distribution

As note earlier, there are two main grain-marketing systems in Ghana. The traditional marketing system dominated by private individuals often termed middlemen, market queens and the alien traders. About 80 % of the grains provided enter the market through this system (Owusu-Ansah, 1989). The parastatal marketing agencies handle about 20 % of the marketing surplus.

4.1.7.1 Background Information of Middlemen

A total of 52 middlemen were involved in the study. Ninety six point two percent were females while 3.8 % were male. The respondents were between the ages of 19 to 65 (Table 21). The age distribution suggests that most (67.3 %) of the middlemen were middle-aged female adults. This is in agreement with the observations of FAO (1997) that in rural communities of sub-Saharan Africa, women are often the major producers and processors of food.

Table 21. Age Distribution of Middlemen

Age	Frequency	Percent
< 20	1	1.9
20 – 29	10	19.2
30 –39	23	44.2
40 – 49	12	23.1
50 and above	6	11.5
Total	**52**	**100.0**

Most (88.5 %) of the middlemen had attained some level of education. Most (73.1 %) had either gone to Middle School or Junior Secondary School (elementary)? Few (13.5 %) had Secondary, Vocational or Commercial school education after elementary school while 1.9 % had teacher training education. About 8 % had never had any form of education while 3.8 % had non-formal education.

4.1.7.2 Marketing of Paddy Rice

Results of the survey indicated that rice is sold either in the form of paddy or milled. The middlemen who mill the paddy for sale to wholesalers, retailers, and food vendors buy paddy rice from farmers.

Fifty one percent of farmers indicated that they always sell paddy rice to middlemen, approximately 26 % sell milled rice while 10.9 % sell both paddy and milled rice. Thus 88.5 % of rice grown in the study area passes through individual middlemen. Only 5.4 % of the farmers indicated that paddy is sold to Farmers' Co-operatives and Kpong Irrigation Project while 6.2 % sell milled rice to consumers and food vendors.

Thirty four percent of farmers sell off their paddy by the second week after harvest. Twenty six percent sell rice by the fourth month after harvest while 24.8 % sell between the fourth and eighth month after harvest. The rest 15.5 % sell their produce between the eighth and twelfth month after harvesting.

On the other hand, 78.8 % of middlemen surveyed indicated that they obtain paddy rice from farmers. About 2 % obtain paddy rice from women paddy rice collectors while 1.9 % obtain paddy rice from other middlemen. The rest 17.3 % obtain milled rice from farmers and millers. The channels of paddy and milled rice distribution are shown in Fig. 9.

4.1.7.3 Marketing of Milled Rice

4.1.7.3.1 Packaging

All the middlemen surveyed market milled rice. Thirty percent of the middlemen package milled rice in 50 Kg sacks obtained from the open market, store or farmers. These sacks have different labels including sugar and imported rice labels. Only 1.9 % of middlemen package rice in sacks with the labels of a Ghanaian company. The rest 70 % do not have any form of packaging. The use of second-hand sacks for packaging milled rice could have adverse effects on rice quality. Such sacks need to be thoroughly disinfected by gassing, since otherwise, they may introduce insects into newly milled rice, thereby facilitating damage during storage.

Most of the middlemen sell their produce on the market in small units (olonka, margarine cup, and nudogba). Twenty seven percent are wholesalers who sell rice in 50-Kg bags while 17.3 % retail in 50-Kg units or by olonka.

There can be no question of the importance of standard weights and measures in marketing. The inability or failure of middlemen to deal in standard quantities can lead to a whole range of marketing problems and malpractice, generally at the expense of both the producer and consumer. This can thus be a disincentive to rice production

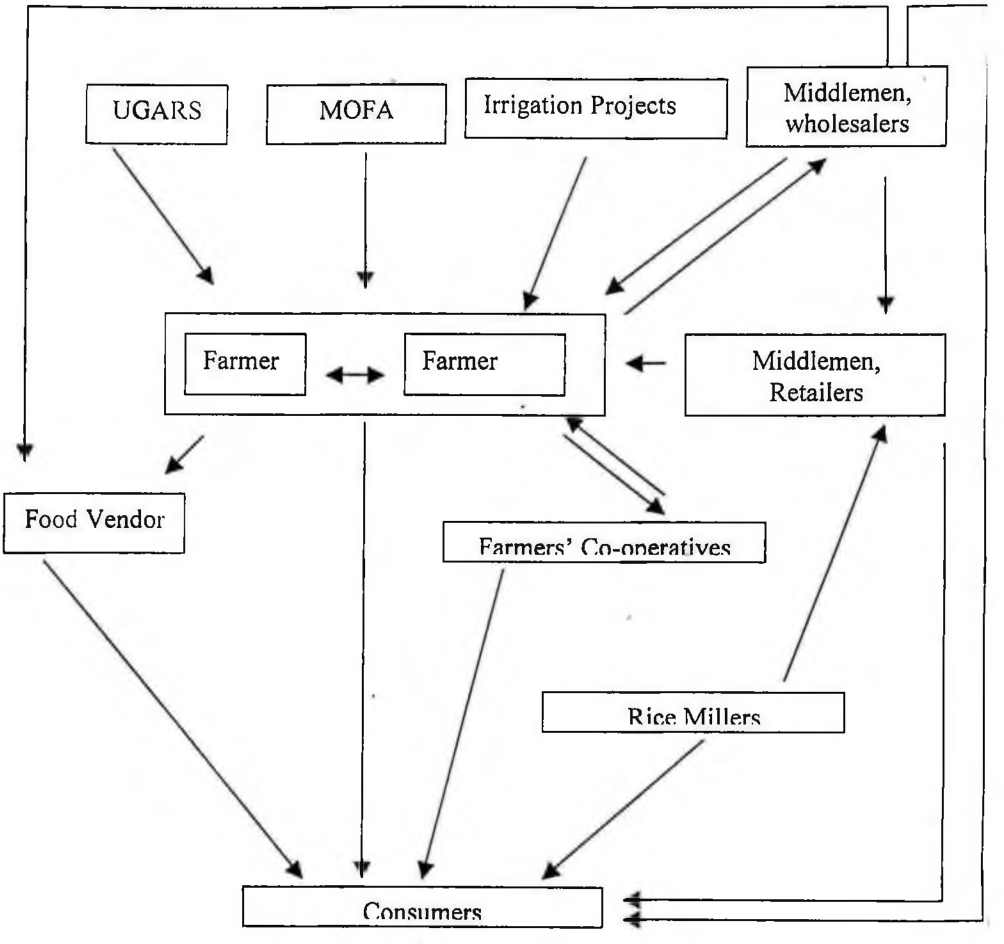


Fig. 9: Channels of rice Marketing and Distribution

UGARS = University of Ghana Agricultural Research Stations

MOFA = Ministry of Food and Agriculture/ Extension Officers

Irrigation Projects = Ashaiman Irrigation Project, Kpong Farms, Kpong Irrigation Project and Afife Irrigation Project

4.1.7.3.2. Rice Varieties

Consumer preference begins with the variety of rice. There are substantial differences between rice varieties in eating and cooking quality. When they can afford it, rice consumers will pay an appreciable premium for varieties they are accustomed to or which appeal to their taste.

Most (55.8 %) middlemen will purchase any variety of rice available. Fifteen percent prefer TOX 18447 because it cooks dry and fluffy, has a good colour, a high expansion ratio and good head rice yield (HRY) and total output. Nine point six percent prefer TOX 3107 because it cooks soft, tastes sweet and is readily bought. Bouake 189 is liked by 15.4 % of the middlemen because it mills well with high HRY and good appearance. Bouake 189 is also preferred because its quality is maintained even when beaten by rain after harvesting. Emo fita and Emo korkor are liked because they expand well during cooking and have good aroma and taste. Emo fita and Emo korkor and Adaesi and Viwonor are very much liked by the people of Kwaebibirem district and Akpafu respectively and were found only in these localities. Some (9.6 %) middlemen however, said they do not buy TOX 3107 because of its high breakage during milling while 3.8 % complained that the variety called Zongo contains too much starch hence they do not patronise it. Some of those who buy all varieties of rice also complained TOX 3107 breaks easily. The susceptibility of TOX 3107 to breakage could be attributed to its slender shape (high length to width ratio).

4.1.7.4. Problems associated with Rice Marketing

Fifty-one farmers (39.5 %) indicated they do not have ready a market for their produce especially during the harvesting period. Some (19.4 %) complained that middlemen purchase paddy on credit and pay by instalments. On the other hand (Table 22 and 23), 25 % of middlemen said milled rice is not rapidly bought while 17.3 % sell their produce on credit. It can therefore be deduced that, the marketing system in the survey area, and probably Ghana involves marketing both paddy and milled rice on credit.

Both farmers and middlemen indicated that rice is sold cheaply during the harvesting period. Farmers also indicated that middlemen dictate the price at which paddy is sold. This is an indication that, during the harvesting period, there is rice glut or near-glut hence farm-gate prices are depressed below the minimum threshold prices, resulting in cash flow constraints for many farmers. Since production costs are said to be high, farmers may lose and thus affecting the next production calendar.

All farmers and 19.2 % of middlemen indicated that milled rice sells less when percentage brokens are high. Thus the quality and total output of milled rice have economic effects on both farmers and traders.

Table 22. Marketing Problems Experienced by farmers

Problem	Frequency		
	G. Accra	Volta	Eastern
Middlemen buy on credit and pay by instalments	18	2	5
No/ Low profits due to selling cheaply	4	8	1
No ready market	19	15	17
No/ low profit due to high production costs	2	2	3
Middlemen dictate prices	9	5	10
Low profits due to breakage during milling	2	-	1
Total number with problems	**54**	**32**	**37**

Table 23. Marketing Problems Experienced by middlemen

Problem	Frequency		
	G. Accra	Volta	Eastern
Sell on credit	5	-	4
Rice not readily bought	6	1	6
Paddy not always available for purchasing (seasonal)		1	4
Broken rice costs less and not readily patronized	5	3	2
Rice sold cheaply when in season		3	
Financial constraints-loans taken to buy rice		3	1
Total number with problems	**16**	**11**	**17**

4.1.8. Performance of Rice Mills

4.1.8.1.Background Information on Mill/ Millers

Sixteen rice mills were visited; five mills each from the Eastern and Volta regions and 6 from the Greater Accra region. The mills visited are listed in Table 24.

Table 24. Name, Location and Total number of Employees at Mills

Mill	Location[1]	Number of Employees
Edenic Mills	Afife, VR	4
Dunyo Farms	Afife, VR	3
UGARS*	Kpong, ER	2
Irrigation Development Authority Mills	Ashaiman, GAR	3
Dunyo Farms	Dawhenya, GAR	1
Otthofio Foods	Dawhenya, GAR	3
Quality Grains Co. Ghana Ltd	Aveyime-Battor, VR	19
BB Rice Mills	Kade, ER	6
Zorko Rice Mills	Kade, ER	2
UG/JICA Integrated Rural Development Project Rice Mills	Kade, ER	4
Kpong Irrigation Project (KIP)	Asutsuare, GAR	4
Station Rice Mills	Asutsuare, GAR	4
Aparfu Nettey's Mill	Asutsuare, GAR	3
Goku Industries	Akuse, ER	5
Agro Deal Ghana Limited	Hohoe, VR	4
Kakpor Rice Mills	Hohoe, VR	3

UGARS*- University of Ghana Agricultural Research Station

[1] - GAR, VR and ER = Greater Accra, Volta and Eastern regions respectively.

Most (62.5 %) of mills have 3-4 employees, 31.25 % had 1-2 employees while the biggest mill visited, Quality Grains Company Ghana Limited had 19 employees.

Most (81.3 %) millers had Middle school or Junior Secondary School education, 12.5 % had secondary school education while 6.25 % had both technical education and special training on milling. This trend is likely to have negative effect on milling since the science of rice has to be well understood for effective work that will result in high quality output. Since these millers mainly learn on the job, depending on the technical knowledge of the trainer, the millers may not have adequate knowledge on the factors affecting milling output. As acknowledged by FAO (1997) improved education and literacy can influence skills and knowledge needed for successful improved agricultural productivity and decisions regarding the use of expenditure and time.

4.1.8.2.Rice drying and storage at mills

Rough rice storage history can affect head rice yield and cooking quality of rice (Villareal *et al.*, 1976; Tamaki *et al.*, 1993). Ninety four percent of the mills had drying floors made of concrete. The capacities of the drying floors ranged from 64-500 m^2 for all the mills except Quality Grains Co. Ghana Ltd, which had drying capacity of 280 tons. The relatively low drying capacity of most of the mills indicates that only limited quantity of paddy can be dried at a particular time. Hence, in time of rice glut, middlemen may have to take turns in drying paddy. This may result in the development of undesirable odours in rice if moisture content of rice is high.

Most (87.5 %) rice mills had some sort of storage facility while 12.5 % had none. The storage facilities were made mainly of aluminium roofing sheets (87.5 %), cement blocks for the walls (62.5 %) and concrete floors (81.25 %). A smaller section of the mills had walls made of wood (18.75 %) and aluminium sheets (12.5 %) and aluminium floors (6.25 %). With the exception of Quality Grains Co. Ghana Ltd and Agro Deal Ghana Ltd, the other mills either store rice in the milling room or a smaller room adjacent to the mill room. The bags of rice are kept on the concrete floor or wooden pallets.

The storage of both paddy and milled rice in mill room can affect rice quality as the temperature and relative humidity during storage affect rice quality. The mill room experiences fluctuations in temperature and relative humidity due to heating up of mills during milling. Rice stored in mill room is therefore likely to gain and lose moisture during storage resulting in temperature- and moisture-induced tensile stresses. Stress in paddy makes paddy more susceptible to fissuring with subsequent reduction in head yield.

Paddy rice is stored by 6.3 % of the mills for up to 24 hours, up to 2 months by 25 % of the mills, up to 6 months by 31.3 % of the mills and between 6 and 12 months by 25 % of the mills.

Paddy rice is stored at room temperature at all the mills except Quality Grains Co. Ghana Ltd., where paddy rice is stored at a controlled temperature of 14 – 16°C. Sixty nine five percent (69.5 %) of mills also kept milled rice for varying periods and usually up to a year. The capacity of the storage facilities are shown in Fig. 10. It ranges from $120m^3$ – 6600 tonnes. The storage capacity of Quality Grains Co. Ghana Ltd is 6600 tonnes while that of the University of Ghana Agricultural Research Station, Kpong, is 50 tonnes.

4.1.8.3. Milling Capacities

Rice mills may be classified as large, medium or small scaled depending on the milling capacity. A large mill will have a daily production of 100 tons rice or more whereas the medium and small mills will have a daily output range of 50 – 100 tons and 50 tons and below respectively (FAO, 1982). Thus most of the mills surveyed were small and medium scale, single pass, and rubber roller mills. The installed (maximum) and actual hulling and milling capacities (Fig. 11) indicate that most of the mills surveyed produce under capacity.

It was found that the hulling and milling capacities of each of the mills were the same. This is because all the mills produce white milled rice hence rice dehulled is whitened. Actual capacities are averages of amount produced in eight-hour periods. Ten out of the 16 mills were conventional one-pass type, 3 were two-pass types, whilst 1 was a multi-stage type. Milling of rice in multiple stages reduces fissuring. The predominant use of single-pass type mills therefore implies possible reduction in head rice yields. Information on the milling capacities of 3 of the mills could not be obtained because millers did not know. Information on number of hours of mill operation per day and days per month could also not be obtained because most of the mills work on custom basis only.

Fig. 10. Storage Capacities of Rice Mills (actual)

A= Edenic Mills, Afife

B= Dunyo farms, Afife

C= IDA Mills, Ashaiman

D= Dunyo farms, Dawhenya

E= Otthofio Foods, Dawhenya

F= University of Ghana/ JICA Rice Mills, Kade

G= Kpong Irrigation Project (KIP) Mills, Asutsuare

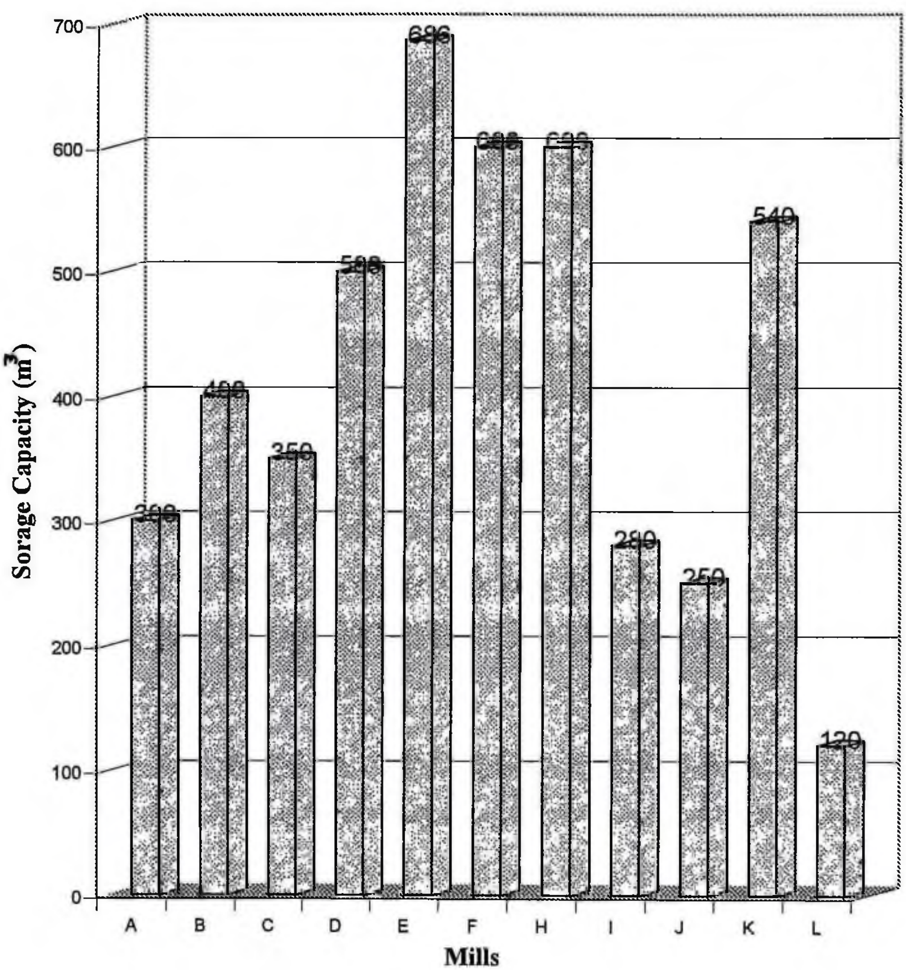
H= Station Rice Mills, Asutsuare

I= Aparfu Nettey's Rice Mills, Asutsuare

J= Goku Industries, Akuse

K= Agro Deal Ghana Limited, Hohoe

L= Kakpor Mills, Hohoe



Sorage Capacity (m³)
700
600
500
400
300
200
100
0
686
350
280
250
540
120
A
B
C
D
E
F
H
I
J
K
L
Mills

Fig. 11. Installed and Actual Milling Capacities of Rice Mills

A= Edenic Mills, Afife

B= Dunyo farms, Afife

C= University of Ghana Agricultural Research Station Mills, Kpong

D= IDA Mills, Ashaiman

E= Dunyo farms, Dawhenya

F= Otthofio Foods, Dawhenya

G= Quality Grains Co. Ghana Limited Mills

H= BB Mills, Kade

I= Zorko Rice mills, Kade

J= University of Ghana/ JICA Rice Mills, Kade

K= Kpong Irrigation Project (KIP) Mills, Asutsuare

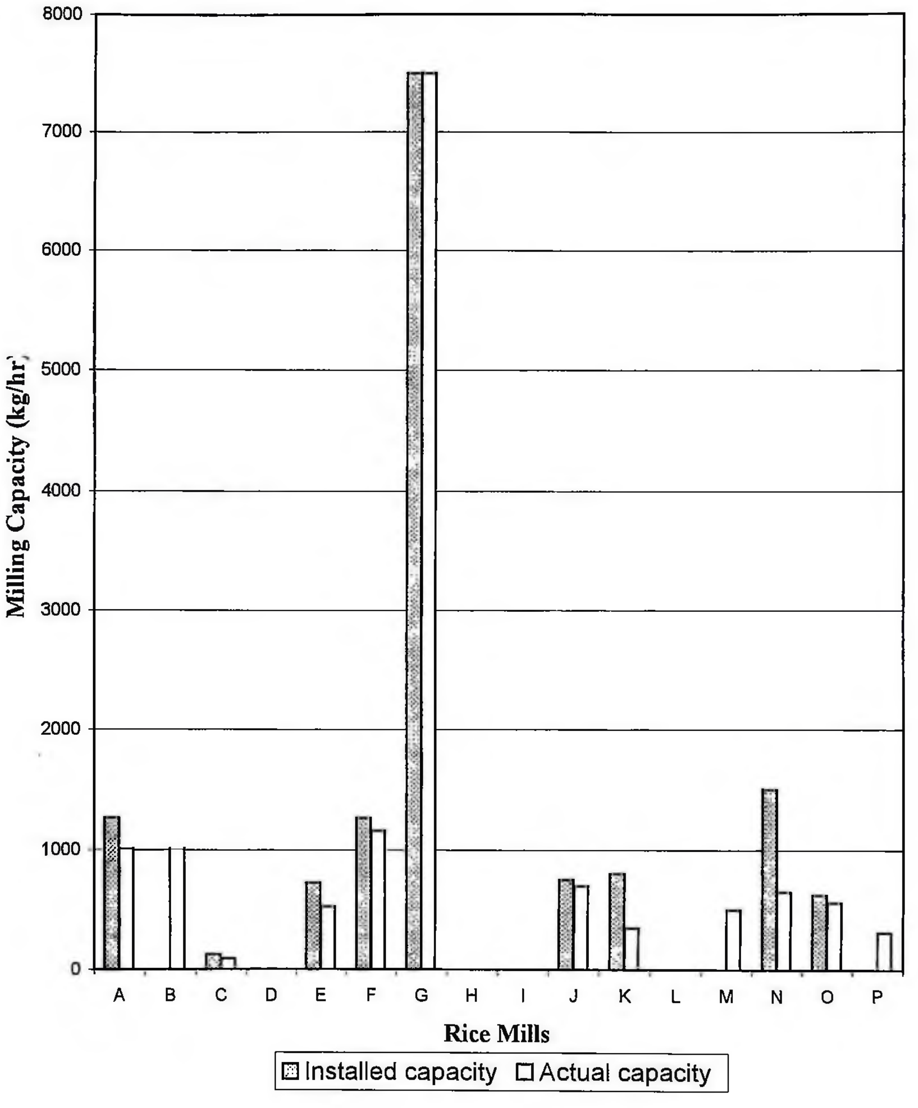
L= Station Rice Mills, Asutsuare

M= Aparfu Nettey's Rice Mills, Asutsuare

N= Goku Industries, Akuse

O= Agro Deal Ghana Limited, Hohoe

P= Kskpor mills, Hohoe


8000
7000
6000
5000
4000
3000
2000
1000
0
Milling Capacity (kg/hr)
A B C D E F G H I J K L M N O P
Rice Mills
Installed capacity
Actual capacity

4.1.8.4.Milling Yields

The milling yield or outturn is the percentage of white rice obtained from the paddy. Factors influencing milling outturns include the uniformity of the paddy, the variety of paddy shelled, the condition of the paddy, type of machine (the type of machine used by each of the mills are recorded in Appendix 5), the condition of the mill as well as skill of the mill operator (Pillaiyar, 1988).

Ten mills gave their total milling yields, which are recorded in Table 25 while the other 6 could not tell. The inability of the mills to give precise answers regarding milling yields is mainly because all the mills except Quality Grains Co. Ghana Ltd mill rice on custom basis – paddy is milled for a set price - hence the millers do not keep records of milling efficiency.

The official milling outturns expected from milling good quality paddy ranges from 65-75 % rice. The maximum permissible brokens (in Ghana's grade 5 rice) is 35 %. However, from the laboratory analysis, all the mills produced broken rice percentages exceeding the 35 % maximum for grade 5 long grain rice except for UG/ JICA, and Zorko rice mills, and Agro Deal Ghana Ltd in the milling of Emo korkor and Viwonor varieties.

Quality Grains Co. Ghana Ltd have the highest total rice recovery rate of 75 %, followed by the University of Ghana/ JICA Integrated Rural Development Project Rice mills, Kade, which has a total recovery rate of 74.8 %. Both Zorko rice mills and Agro Deal Ghana Ltd reported having milling yields between 60 and 70 %. Kpong Irrigation

Project mill, Goku Industries and Aparfu Nettey's rice mills have milling outturns of 50-60 % while BB mill and Station mill reported usually having average milling outturn of 50 %. The UGARS mills, Kpong reported having a total recovery rate of 61 %.

Table 25. Rice Recovery Rates of the different Rice Mills

Mill	Total output (%)	Head rice yield (%)[a]		Brokens (%)[b]	
		Miller's response	Lab. result	Miller's response	Lab. result
UGARS, Kpong	61	-	49.8		50.2
Quality Grains, Aveyine	75	75	*	25	*
BB Mills, Kade	50	50	*	50	*
Zorko Mills, Kade	60	50-80	73.0-83.0	50-80	26.1
UG/JICA, Kade	74.8		68.5		31.5
KIP, Asutsuare	50-60		47.0-60.0		39.5
Station Mills, Asutsuare	45-55	-	*		*
Aparfu Nettey, Asutsuare	50-60		*		*
Goku Industries, Akuse	59.5		50.1		49.9
Agro Deal, Hohoe	60-70	-	47.6-71.6		28.4-52.4
IDA, Ashaiman			48.7-60.8		39.2-51.3
Edenic, Afife			53.7-56.0		44.0-46.3
Othoffio, Dawhenya		-	19.9-57.2	-	42.8-81.1
Dunyo Farms, Afife	-		78.6	-	21.4

-No response

*No sample taken from mill

a/b: these are percentages of the total output

All the mills visited produce white milled rice by whitening. No form of rice enrichment and/or fortification is done.

4.1.8.5. Maintenance of Mills

The ability to maintain milling machines is an important variable in the performance of rice mills in addition to the quality of paddy and operator skill. Most (62.5 %) of the mills said they have facilities to undertake repair and maintenance work of the mills. The maintenance schedule of all the mills in exception of Quality Grains Co. Ghana Ltd where the schedule could not be obtained however, indicated that they do not have precise or definite maintenance schedules. Parts such as bearings, rubber rollers, sieves and belts are repaired and replaced when the need arises, such as when the belt melts, or when rubber rollers wear out and bearings and sieves are destroyed. The main maintenance procedure carried out by the mills includes dusting and greasing or oiling parts regularly or when necessary. Kpong Irrigation Project and the UG/ JICA mills however, indicated that the mill is dismantled to remove stones that may get stack in sieves every two months and 2 weeks respectively.

The parts of the mill frequently changed or replaced include rubber rollers (68.75 %), sieve (50 %) and bearings and belts (37.5 %).

It is important that mills are maintained. Regular servicing of mills will promote milling efficiency; head yields as well as prolong the durability and reliability of mills.

Twenty five percent of the mills have been in use for less than 2 years, 18.75 % between 3 and 5 years, 12.5 % each between 5 – 10 years and 10 – 20 years respectively while 18.75 % have been in use for more than 20 years.

4.1.8.6. Rice Processing Machinery and Operations

4.1.8.6.1 Cleaning

Eleven of the mills surveyed (68.75 %) were equipped with pre-cleaning devices, most of which remove chaff from paddy. All the mills had at least one aspirator that blows the chaff off after dehulling and whitening while 31.25 % of the mills were equipped with seed separators. Seven out of the 16 mills were equipped with destoners and electromagnetic/ gravity separators that are used to remove stones/ dense materials and ferrous materials respectively, from the milled rice.

Cleaning is an important step in producing high quality milled rice. According to USDA standards (USDA, 1976), the highest grade (US No. 1) of milled rice has maximum limit of 1 seed in 500 g. If the milled rice contains 2 seeds in 500 g, rice is down graded to US No. 2 rice, although other specifications of No. 1 are met. It is therefore necessary that all mills are equipped with efficient cleaning devices as cleaning of rice affects marketability.

4.1.8.6.2 Shelling

The first step in the actual milling of rice is to remove the hulls (shelling). The Sheller is normally set to shell about 95 % of the incoming rough rice. In this survey, only 18.8 % of the mills were observed to have paddy separators. The aim of the paddy separator is to separate paddy rice from brown rice and send it back to the shelling machine and in many instances, to what is called the return Sheller set aside for the specific purpose of shelling rough rice returned from the paddy machines. The low percentage of paddy separators is because 62.5 % of the mills surveyed were of the one-pass type. With the exception of Quality Grains Co. Ghana Ltd that had a paddy separator type PSL-24-AH, information on the type and model of the other separators could not be obtained. The efficiency of dehulling and paddy separation could also not be obtained because the millers do not take records of the performance of the mills.

4.1.8.6.3 Whitening

All the mills surveyed produce white raw milled rice. Only Quality Grains Co. Ghana Ltd is equipped with a parboiling facility. The technology employed in milling/ whitening is mainly small to large-scale rubber rollers (93.8 %). Goku Industries situated in Akuse, is the only mill that uses small-scale steel huller.

The use of rubber rollers mainly compared with the use of the steel huller in the milling of raw rice is advantageous because milling using the steel huller is known to result in lower total and head rice recovery, mixing of bran with husk, and relatively high power consumption (Grist, 1975). Due to the resilience of rubber rollers, neither the bran layers of the brown rice are damaged nor do sound kernels break during milling. Consequently, the rubber roller is considered the best equipment for raw rice. Fifty percent of the mills were Satake types obtained from Japan (Appendix 5).

There was noise production in 87.5 % of the mills visited and various degrees of dust production in 62.5 %. However, none of the mill operators had ear and nose masks.

4.1.8.6.4 Polishing

In rice milling operations, the final step after whitening, when the milled rice is aspirated to remove loose bran and/ or passed through a machine called a brush or polisher is termed polishing. Only Quality Grains Co. Ghana Ltd polish milled rice after whitening hence samples taken from the mills had particles of loose bran on their surfaces. Polishing would have given the milled rice a more polished or translucent surface. However, the practice of not polishing white raw milled rice in Ghana has a positive influence on the higher mineral content of locally milled rice.

4.1.8.6.5 Sizing

Milled rice is sized by length to separate whole kernels (head rice) from the brokens. Based upon length, the brokens may be separated into second heads, screenings and brewers rice. Thirteen out of the 16 mills surveyed do not have any form of sizing or grading. The University of Ghana Agricultural Research Station at Kpong and Otthofio foods, Dawhenya separate the brewers rice, the smallest sized brokens from the other sizes of milled kernels while Quality Grains Co. Ghana Ltd separate all brokens from head rice. In addition, various grades of the paddy rice are separated and classified by Quality Grains Co. Ghana Ltd before milling. The milling machine is set to suit paddy sizes before milling. The inability of mills to grade milled rice have effect on consumer preference and choice of imported rice over locally milled rice. If local milled rice can be graded, different categories of consumers will patronise the various grades and local rice could gain a greater market share.

Fifty percent of mills have weighing scales. However, since milling is done mainly on custom basis, weight of milled rice is taken only when demanded by the customer. It is mainly the wholesalers who bag their product in 50-kg units do weighing of milled rice.

4.1.8.7 Factors affecting Milling Quality

4.1.8.7.1 Opinion of Middlemen

Middlemen were asked to state, in their opinion, the factors that affect milling quality. Seventy eight point eight five percent (18.5 %) stated moisture content of the paddy as the single most important factor affecting milling quality of rice. They stated that drying rice to appropriate moisture levels results in higher head rice yield. The other factors mentioned are recorded in Table 26. These factors range from pre- and post-harvest management practices to genetic factors. This is an indication that the middlemen are knowledgeable about some of the factors affecting milling quality. None of them however, mentioned the conditions of the mill as affecting rice quality.

Table 26. Opinion of middlemen about Factors affecting quality of milled rice

Factor	Effect of factor	Frequency	Percent
Improper/ untimely fertilizer application	Poor quality milled rice, chalky and broken kernels	6	11.6
Varietal differences	Influences milling quality	4	7.7
Good pre- and post-harvest management	Facilitates higher HRY and total output	11	21.2
Heat damage	Breakage and discolouration of milled grains	6	11.6
Wetting of rice e.g. beaten by rain	Breakage and discolouration of milled grains	8	15.4
Extraneous matter in paddy	Rice breakage, impure rice	2	3.8
Impromptu drying after harvest	Breakage during milling	1	1.9

4.1.8.7.2 Condition of the Mill

Millers were asked if there were any problems with their mill that they think affect milling quality and output. Nine of them said their mills were in good shape whereas 7 said they have problems that affect milling quality and output. Agro Deal Ghana Ltd mill do not have a destoner hence milled rice contain stones. Station mills, Asutsuare had worn out rubber rollers that the miller said promote rice breakage during milling and also indicated that when sieves are worn out, rice get contaminated with bran. Quality Grains Co. Ghana Ltd also complained of inadequate aspiration in one of the processing steps due to low pressure. Otthofio foods, Dawhenya cannot separate head and broken kernels efficiently due to the sizes of its sieves hence very thin impurities such as pieces of straw do mix with the milled product.

The Irrigation Development Authority (IDA) rice mills at Ashaiman reported that whenever rubber rollers wear out, breakage of kernel increase and when sieves wear out, separation of bran from grains becomes less effective. Both Edenic mills and Dunyo farms, Afife also said good quality product is obtained when rubber roller is new.

4.1.8.8 Major Problems Faced in Rice Milling

The survey also looked at the major problems faced by millers in rice milling. Four of the mills (IDA mills, Ashaiman; Otthofio foods, Dawhenya; Station mill, Asutsuare and Goku industries, Akuse) indicated that negative pre- and post-harvest handling and management of the grains results in low HRY, which they said, is undesirable. They also indicated that when rice is not well dried before milling, the hull chokes the sieves resulting in production of poorer quality rice.

Lack of spare parts, particularly sieve and rubber rollers were also mentioned as major constraints. Rubber rollers, which they indicated wear off very frequently was also said to be very expensive and not readily obtained since it has to be imported from other countries due to non-availability locally. The sieves were also said to tear easily due to presence of stones in grains.

Power fluctuations and seasonal production of paddy were also mentioned. Most of the mills visited indicated that they mill rice mainly in the harvesting period and a little beyond, usually between September and January. During the planting season, most of the paddy produced in the previous season would have been milled hence demand for milling goes down.

Zorko rice mills, Kade indicated that since paddy is dried by sun drying, it is difficult to dry paddy during the rainy season hence demand for milling operations decrease. The miller lamented on high electricity bills as well as non-availability of credit facilities for millers, which he said would have helped improve the milling facilities and hence operations.

Aparfu Nettey rice mills, Asutsuare said its major problem is the production of dust during milling. Agro Deal Ghana Ltd, Hohoe indicated that, there is no thresher in the community hence threshing is done by beating panicles on concrete floors. This method of threshing produces paddy with stones and other foreign materials, resulting in frequent destruction of sieves and breaking down of milling machine.

Quality Grains Co. Ghana Ltd indicated that the inability of one of its aspirators to properly aspirate bran from milled product is its major problem.

The inability of middlemen to pay promptly for the services of mills was also mentioned. BB mills, which also market milled rice, indicated that they do not have ready markets for milled rice.

4.2 LABORATORY ANALYSIS

4.2.1 Properties of Paddy Rice

4.2.1.1 Dockage

Dockage is defined in the US standards for rice as all matter other than rice that can be readily removed from rough rice by use of appropriate sieves (USDA, 1976). The presence of foreign matter in paddy rice can have an effect on the milling quality and output. Foreign matter in paddy such as stones could also affect the operation of the mills and damage sieves. The amount of foreign matter found in the paddy samples ranged from 0.25 % to 1.91 %.

4.2.1.2 Moisture Content

Moisture content (MC) is the most important criterion for rough rice. Its effects are of primary importance as far as keeping properties of rice during storage are concerned. This is because under practical storage conditions, moisture level is usually the factor most responsible for controlling the rate of deterioration of the grain.

Paddy, which has been dried and either stored or brought to the mill for milling was collected from farmers and mills and moisture content was determined. The mean moisture content of the paddy ranged from 12.42 % to 17.30 % (Appendix 6). The moisture contents commonly accepted for 'safe' storage of rough rice are 13 % for less than 6 months and 12 % for long-term storage. All except one of the samples meant for storage had moisture content levels higher than 13 %. Thus this paddy can be stored only for limited period of time and less than 6 months otherwise; high levels of spoilage could be experienced. The samples meant for milling had lower moisture levels of 12.42 to 13.81 %.

4.2.2 Physical Properties of Raw Milled Rice

The physical properties of rice correlate directly with its market value. The objective of rice mill operation is to produce a white, whole or head rice product that is essentially free of bran and foreign matter and which contains a minimum of broken kernels. The quality of rice is closely related to the cleanliness, purity and quality of its milled whole kernels (Webb and Stermer, 1972).

4.2.2.1 Foreign Matter

The quantity and character of impurities obviously affect the value of a lot. In addition to reducing the quantity of usable rice, lowering milling yields and affecting the value of rice for food, certain impurities can also damage the processing equipment. Impurities in milled rice also affect flavour of cooked rice.

The Ghana standard specification for milled rice GS 61: 1990 (appendix 15) specifies the standard requirements for milled rice in Ghana. The permissible limit for foreign matter as specified by the Ghana standard specification for milled rice is between 0.5 % for a grade 1 rice to 1 % for grade 5 rice. From the results obtained (Table 27), it will be noted that percentage foreign matter of all the samples ranged from 0.02 % for Adaesi (Agro Deal Ghana Ltd) to 0.76 % for TOX 3107 from Edenic mills, Afife. Thus the percentage extraneous matter is within the acceptable range in Ghana. All the samples can be said to fall within Ghana rice grade 1 and 2 with respect to percentage foreign matter alone except TOX 3107 samples from University of Ghana Agricultural Research

Station, Kpong, Edenic mills, Afife, and IDA mills, Ashaiman, which fell within Ghana rice grade 1 to 3.

Table 27. Dockage, Moisture Content and other Fractions of Raw Milled Rice

Variety	Mill	Foreign matter (%) [a]	Moisture [b] (%)	Fraction other than foreign matter (%)		
				Discolored [a]	Brokens[a]	Chalky [c]
Bouake 189	IDA, Ashaiman	0.35 (1,2)	13.50	0.04 (4,5)	51.31*	0.54
Bouake 189	KIP, Asutsuare	0.19 (1,2)	13.07	0.00 (1,2,3)	53.02*	0.37
Bouake 189	Goku, Akuse	0.38 (1,2)	10.41	0.00 (1,2,3)	49.86*	1.07
Viwonor	Agro Deal, Hohoe	0.09 (1,2)	11.39	0.00 (1,2,3)	28.41*	0.00
WITA 9	KIP, Asutsuare	0.09 (1,2)	12.58	0.00 (1,2,3)	51.51*	0.31
WITA 9	IDA, Ashaiman	-	13.78	0.24 (4,5)	39.17*	0.14
Emo korkor	UG/ JICA, kade	0.24 (1,2)	12.38	0.41 (4,5)	31.46*	1.56
Emo korkor	Zorko, kade	0.44(1,2)	12.63	0.69 (4,5)	26.17*	0.48
TOX 3107	UGARS, Kpong	0.71 (3,4,5)	10.79	0.00 (1,2,3)	50.20*	0.00
TOX 3107	Edenic, Afife	0.76 (3,4,5)	13.35	0.16 (4,5)	46.30*	1.14
TOX 3107	Otthofio Foods, Dawhenya	0.21 (1,2)	12.30	0.00 (1,2,3)	81.14*	0.12
TOX 3107	IDA, Ashaiman	0.66 (3,4,5)	11.54	0.00 (1,2,3)	50.45*	0.00
TOX 3108	IDA, Ashaiman	0.03 (1,2)	13.15	0.21 (4,5)	39.34*	0.02
TOX 18447	Dunyo farms, Afife	0.10 (1,2)	11.74	0.08 (4,5)	21.41 (3)	0.46
Adaesi	Agro Deal, Hohoe	0.02 (1,2)	11.34	0.00 (1,2,3)	52.39*	0.02
Perfumed	Agro Deal, Hohoe	0.22 (1,2)	11.73	0.00 (1,2,3)	41.32*	0.13
Perfumed	Edenic, Afife	0.08 (1,2)	13.41	0.20 (4,5)	44.04*	0.91
Perfumed	Otthofio Foods, Dawhenya	0.34 (1,2)	12.91	0.11 (4,5)	42.77*	0.78
Perfumed	IDA, Ashaiman	0.24 (1,2)	13.00	0.01 (4,5)	42.41*	0.01

[a] Figures in bracket – grading based on Ghana standard specification for milled rice – GS 61: 1990. Grading took into consideration, sizes of grains (long, medium or short), also based on GS 61: 1990.

[b] Moisture content values do not exceed maximum specified value of 13.5 % (m/m) fresh weight basis – GS 61: 1990

[c] All values fall within Ghana standard specification for milled rice – GS 61: 1990 grade 1

* Values do not fall within Ghana standard specification for milled rice. Values higher than maximum values prescribed for grades

4.2.2.2 Fractions Other Than Foreign Matter

Ghana standard specifications for milled rice permits 0-1 % discoloured grains, 2-15 % chalky and 5-35 % broken kernels in Ghana rice grade 1-5 respectively.

4.2.2.2.1 Discoloured Grains

Nine of the samples fall within Ghana rice grades 1 – 3 as specified by GS 61: 1990, as they contained no discoloured kernels (Table 27). The rest of the samples fell within Ghana rice grade 4 and 5.

Discoloration can occur during drying operations, or during subsequent storage and handling. Wet weather after the rice has matured, can cause serious types of staining and promote the growth of fungi. High moisture conditions in storage can also result in the development of red to brown stains known as heat damaged kernels. This is probably why the Emo korkor recorded the highest percentage of discoloration as middlemen from Kade reported discoloration due to high temperature during the storage of paddy. Farmers in this area also do not dry rice before storage. Thus there is the possibility of high moisture conditions during the storage of paddy rice.

4.2.2.2.2 Chalky Grains

Studies (Tashiro and Ebata, 1975; Tashiro and Wardlaw, 1991) have shown that high temperatures during specific stages of grain development tend to increase the occurrence of chalk in rice grains.

The US Rice Grading Service classifies chalky kernels as kernels which are one-half or more chalky (UDSA, 1976) while the Ghana standard specification for milled rice, GS 61: 1990 classifies chalky grain as a kernel, whole or broken of which at least half of the portion is opaque, milky white in colour and/or brittle in nature. The type as well as the amount of chalk is important to some processors of rice, as certain types of chalk affect the quality of their particular processed product more than other types. Chalky rice not only detracts from general appearance, but is also usually weak and, therefore, breaks up easily during milling, with a subsequent reduction in the yield of milled rice.

The percentage chalkiness of the grains ranged from 0 to 1.56 %. These are within the permissible limit of Ghana standard specification for milled rice. With respect to chalkiness alone, the sample could be said to be grade 1. Since high temperature seems to be the main cause of chalkiness, it can be concluded that the temperature during the development of grains in the study area was normal or not too high.

4.2.2.2.3 Broken Grains

Except for TOX 18447, Viwonor and Emo korkor samples whose percentage brokens were below the maximum permissible value of 35 % for grade 5 long grain rice and 30 % for grade 5 medium grain rice, all the rice samples from the various mills showed very high percentage of broken kernels (Table 27). TOX 3107 from Otthofio foods, Dawhenya recorded the highest percentage brokens of 81.14 %. These differences could be attributed to either varietal or pre- and post-harvest handling of the kernels or the conditions and setting of rice mills. However, the lower percentage brokens in the Emo korkor and Viwonor varieties are more likely due to varietal integrity rather than machine settings. This is because Adaesi for instance, which was milled in the same mill (Agro Deal Ghana Ltd, Hohoe) as Viwonor, recorded a much higher (52 %) broken percentage.

Rice milling is of great economic importance to the rice industry, particularly, since rice breakage is attributed primarily to the milling operation and since broken rice is worth about half that of whole rice. Matthews and Spadaro (1975) have shown that half of the breakage occurs during harvesting and the remainder occurs in the subsequent handling and milling. The overall economic effect of rice breakage can be seen in the lower prices of locally milled rice compared with the imported varieties though production costs are high. This is probably the reason why both farmers and middlemen are making low profits.

The uniformity of paddy as well as the setting of the milling machine are also important factors that are likely to affect percentage brokens. It was observed that all varieties and hence sizes and uniformity brought to the mill, are milled without adjusting the machine settings to suit the particular size. From a nutritional standpoint, brokens are the same as whole grains. However, broken rice gets soft and mushy when cooked. Brokens also tend to have more bran, which affects flavour.

No insect damaged kernels, red grains and insect parts were found in the rice samples. This is probably because the samples were taken from newly harvested rice that had minimum storage period.

4.2.2.3 Moisture Content

The moisture content of the raw milled rice samples ranged between 10.41-13.78 %. The moisture content of rice prior to cooking affects texture. If the moisture content is below 13 %, the quick movement of water will cause cracking. Thus the samples with lower moisture have tendency of cracking during cooking and hence a poorer cooking texture. Imported rice samples bought from the Ghanaian market for comparison, had moisture range of 12.37-13.97 %, indicating that the imported rice samples have higher moisture contents on the average.

4.2.2.4 Grain Size, Shape, Weight and Uniformity

Since rice is produced and marketed according to grain size and shape, the physical dimensions, weight and uniformity are of prime importance. The dimensions of rice are important in grading, in developing new varieties, in cleaning and grading equipment, in drying operations and in processing

4.2.2.4.1 Grain Size and Shape

Grain-type categories are based upon three physical qualities: length, width and weight. From the results, the various rice varieties from the different mills fall into various classes (Table 28). Thus size classification based on the GS (1990) and Codex (1995) definitions (Table 28) revealed that TOX 3107, TOX 18447, Adaesi and three samples of perfumed rice are long grain varieties, TOX 3108, WITA 9, Viwonor and the perfumed rice sample from Otthofio foods, Dawhenya as well as Bouake 189 from Kpong Irrigation Project and Goku Industries are medium grain samples. Emo korkor is classified as short grain variety based on Codex (1995) and a medium grain variety based on GS 61: 1990.

Grain size classification based on FAO (1975) definitions (Table 28) indicated that Bouake 189, Viwonor, WITA 9, TOX 3108, TOX 18447,Adaesi, perfumed and TOX 3107 from two sources each are long grain types whilst the other source of TOX 3107 and perfumed rice samples are extra long grain types. Emo korkor is medium or long grain-type.

Shape classification by both Codex (1995) and FAO (1975) showed that Bouake 189, Viwonor, Emo korkor, TOX 3108, Adaesi and TOX 18447 are medium shaped type varieties or what is described as bold grains (FAO, 1975). Two samples of perfumed and 3 of TOX 3107 are long or slender shape types.

Classification based on both length and length/width ratio (Codex, 1995) indicated that all the samples except Emo korkor are long grain varieties.

In practical terms therefore, it will imply that the various varieties of rice will be marketed as different grades at different marketing centres or countries. This will imply different economic values for the same rice on the international market.

Table 28: Grain-type classification based on Ghana (GS 61: 1990), Codex (1995) and FAO (1975) standards

Table 28: Grain-type classification based on Ghana (GS 61: 1990), Codex (1995) and FAO (1975) standards

Variety	Mill	Length (L) (mm)	Width (W) (mm)	L/W ratio	GS 61:1990	Codex (1995)			FAO (1975)	
					Size	Size	Shape	Combination of L&L/W	Size	Shape
Bouake 189	IDA,	6.60±0.397	2.36±0.117	2.79	Long grain	Long grain	Medium grain	Long grain	Long grain	Bold/medium
Bouake 189	KIP	6.44±0.423	2.34±0.091	2.76	Medium grain	Medium grain	Medium grain	Long grain	Long grain	Bold/medium
Bouake 189	Goku	6.56±0.240	2.34±0.114	2.77	Medium grain	Medium grain	Medium grain	Long grain	Long grain	Bold/medium
Viwonor	Agro Deal	6.56±0.352	2.20±0.147	2.98	Medium grain	Medium grain	Medium grain	Long grain	Long grain	Bold/medium
WITA 9	KIP	6.37±0.245	2.17±0.106	3.35	Medium grain	Medium grain	Long grain	Long grain	Long grain	Slender/long
WITA 9	IDA	6.40±0.330	2.17±0.142	2.95	Medium grain	Medium grain	Medium grain	Long grain	Long grain	Bold/medium
Emo korkor	UG/JICA	6.02±0.337	2.76±0.090	2.18	Medium grain	Short grain	Medium grain	Long grain	Long grain	Bold/medium
Emo korkor	Zorko	5.99±0.561	2.80±0.080	2.14	Medium grain	Short grain	Medium grain	Medium grain	Medium Extra	Bold/medium
TOX 3107	UGARS	7.12±0.307	2.12±0.091	3.36	Long grain	Long grain	Long grain	Long grain	Long	Slender/long
TOX 3107	Edenic	6.64±0.360	2.31±0.0137	2.87	Long grain	Long grain	Medium grain	Long grain	Long grain	Bold/medium
TOX 3107	Otthofio	7.06±0.300	2.12±0.119	3.33	Long grain	Long grain	Long grain	Long grain	Extra Long	Slender/long
TOX 3107	IDA	6.80±0.444	2.10±0.109	3.25	Long grain	Long grain	Long grain	Long grain	Long grain	Slender/long
TOX 3108	IDA	6.44±0.418	2.19±0.127	2.93	Medium grain	Medium grain	Medium grain	Long grain	Long grain	Bold/medium
TOX 18447	Dunyo, Afife	6.71±0.328	2.30±0.110	2.91	Long grain	Long grain	Medium grain	Long grain	Long grain	Bold/medium
Adaesi	Agro Deal	6.75±0.408	2.36±0.170	2.86	Long grain	Long grain	Medium grain	Long grain	Long grain	Bold/ medium
Perfumed	Agro Deal	7,05±0.408	2.10±0.098	3.35	Long grain	Long grain	Long grain	Long grain	Extra Long	Slender/long
Perfumed	Edenic	7.02±0.380	2.26±0.152	3.09	Medium grain	Long grain	Long grain	Long grain	Extra Long	Slender/long
Perfumed	Otthofio	6.53±0.348	2.29±0.114	2.85	Long grain	Medium grain	Medium grain	Long grain	Long grain	Slender/long
Perfumed	IDA	6.71±0.371	2.31±0.162	2.90	Long grain	Long grain	Medium grain	Long grain	Long grain	Bold/medium

4.2.2.4.2 Uniformity

The uniformity of seed dimensions affects the functioning and performance of equipment. The uniformity was calculated as the coefficient of variation in the dimension of each representative sample.

From the results (Table 28, Appendix 7), Emo korkor is the variety with the least variability in width followed by Bouake 189 from KIP whilst Bouake 189 from Goku Industries, Akuse, and TOX 3107 from Otthofio foods, Dawhenya and UGARS, Kpong had the least variability in length. The use of these samples, therefore, in milling machines will require less adjustment compared with the other samples, which had relatively higher standard deviations and hence variability. It was also noted that, the variability in length of all the perfumed rice samples was similar. The similarity in variability will thus offer a more accurate or better performance and higher efficiency of milling machine.

The high variability in length and width of kernels of the same variety from different sources could be attributed to factors prevailing during growing period, such as soil type, soil nutrition and weather/rainfall pattern. These variations in uniformity could be contributing factors to breakage levels observed.

4.2.2.4.3 1000-kernel Weight

The index, thousand-kernel weight reflects the density as well as the ability of a commodity to accumulate dry matter. Emo korkor was found to be the heaviest and this may reflect in the yield potential measures. TOX 3107 from Otthofio foods, Dawhenya is the next heaviest after Emo korkor followed by TOX 3108 (Table 29), and TOX 3107 from IDA and UGARS, Kpong. The varieties with the most uniform weight however, are WITA 9 and Bouake 189. The lightest variety was TOX 18447.

4.2.2.5 Bulk Density

Each type or variety of grain when in optimum health, fully mature, etc. has a characteristic bulk density. This is defined as the weight per standard volume measured in a standard manner. Bulk density is a measure of overall quality of grain.

The bulk density of white milled rice is shown in Table 29. The bulk density values ranged from 793.65 Kgm^{-3} for WITA 9 obtained from IDA mills, Ashaiman to 847.96 Kgm^{-3} for Emo korkor. This is partly in agreement with findings of Bhattacharya *et al.*, (1972) which showed that more rounded kernels have greater bulk density than slender ones. However, Adaesi and TOX 3107 from UGARS, Kpong, slender type varieties had equally high bulk density of 847.62 and 840.37 Kgm^{-3} respectively. This can be explained by the fact that other factors such as grain type (long-, medium- or short-grain), moisture content (MC), kernel density and additional physical properties such as kernel shape (length/width ratio), and dimensional characteristics affect bulk density of rice (Fan *et al.*, 1998). It has also been found (Fan *et al.*, 1998) that rice harvested at low MC level (≈ 13 %) have higher bulk density for both brown and white than those harvested at higher MC levels.

The results could also be explained by the degree of milling of the white rice. The rate of bran removal during whitening is affected by the level of conditioned MC and thus the degree of milling (Bennett *et al.*, 1993), which could have possibly affected bulk density. This could be seen in the results of degree of milling (DOM), which indicated

Table 29. 1000-Kernel Weight and Bulk Density of Raw Milled Rice

Variety	Mill	Weight of 1000 kernels (g) [a]	Bulk density (Kgm^{-3})
Bouake 189	IDA, Ashaiman	23.38	813.14
Bouake 189	KIP, Asutsuare	23.17	840.47
Bouake 189	Goku, Akuse	22.84	833.35
Viwonor	Agro Deal, Hohoe	21.96	826.67
WITA 9	KIP, Asutsuare	22.45	833.34
WITA 9	IDA, Ashaiman	22.78	793.65
Emo korkor	UG/ JICA, kade	26.52	844.09
Emo korkor	Zorko, kade	28.51	847.96
TOX 3107	UGARS, Kpong	23.70	840.37
TOX 3107	Edenic, Afife	22.71	826.53
TOX 3107	Otthofio Foods, Dawhenya	24.58	833.43
TOX 3107	IDA, Ashaiman	22.06	813.19
TOX 3108	IDA, Ashaiman	23.91	806.49
TOX 18447	Dunyo farms, Afife	21.80	819.68
Adaesi	Agro Deal, Hohoe	22.89	847.62
Perfumed	Agro Deal, Hohoe	22.24	833.53
Perfumed	Edenic, Afife	22.67	819.79
Perfumed	Otthofio Foods, Dawhenya	23.26	833.44
Perfumed	IDA, Ashaiman	23.72	806.59

[a] = means, based on dry matter basis

that samples with higher DOM, such as Adaesi and TOX 3107 from UGARS, Kpong, and perfumed rice from Agro Deal Ghana Ltd. recorded higher bulk density values than samples with lower degrees of milling.

The bulk density was partly affected by moisture content ($r^2 = 0.21$) (Appendix 8.).

4.2.2.6 Colour

Results of objective colour measurement using the Hunter Lab colour meter are shown in Table 30. The colour difference is a measure of the distance in colour space between two colours (black and white) and it is a single colour function of the Hunter tristimulus data. It indicates the lightness in the colour of a product.

Mean Hunter L* values observed ranged from 89.25 for Viwonor to 98.55 for Adaesi. The closer the value is to 100, the lighter the colour value (L*) of the product (deMan, 1990). Thus, Adaesi was the lightest among the samples while Viwonor has the darkest colour. Range of 89.25 to 98.55 indicates variations in lightness of the samples.

The level of redness was highest in Viwonor (a red coloured rice variety) and lowest in TOX 3107 obtained from Edenic mills, Afife and Adaesi. The mean redness (a*) values ranged from 0.06 to 3.76 for TOX 3107 from Edenic mills and Viwonor respectively.

The b* values observed ranged from 8.26 for Adaesi to 11.14 for WITA 9 obtained from Kpong Irrigation Project mills, Asutsuare indicating variations in the levels of yellowness in the samples.

Analysis of Variance (Appendix 9) on the data indicates very significant differences in the levels of lightness, redness and yellowness ($p < 0.05$) among the various varieties.

Table 30. Hunter L*, a*, b* Values and Total Colour Difference (ΔE) of Rice

Variety/ Mill	Hunter values			ΔE
	L*	a*	b*	
B-189/ IDA	94.56 ± 0.08	0.53 ± 0.01	11.11 ± 0.12	11.98
B-189/ KIP	94.75 ± 0.11	0.86 ± 0.02	9.93 ± 0.11	11.23
B-189/ Goku	93.16 ± 0.42	0.56 ± 4.7×10^{-3}	10.50 ± 0.09	12.89
Viwonor/ AD	89.25 ± 0.22	3.76 ± 0.02	11.09 ± 0.25	17.03
WITA 9/ KIP	95.00 ± 0.09	0.27 ± 0.01	9.79 ± 0.17	10.93
WITA 9/ IDA	93.35 ± 0.32	0.40 ± 0.02	11.14 ± 0.21	13.02
Emo korkor/ UG/JICA	94.88 ± 0.20	0.73 ± 0.00	10.75 ± 0.20	11.52
Emo korkor/ Zorko	95.54 ± 0.43	0.46 ± 0.03	10.41± 0.43	10.77
TOX 3107/ UGARS	94.89 ± 0.18	0.49 ± 0.01	9.88 ± 0.15	11.07
TOX 3107/ Edenic	95.89 ± 0.26	0.06 ± 0.02	8.61 ± 0.04	9.61
TOX 3107/ Otthofio	96.36 ± 0.19	0.34 ± 0.01	8.77 ± 0.24	9.25
TOX 3107/ IDA	96.28 ± 0.27	0.18 ± 0.01	10.04 ± 0.28	9.95
TOX 3108/IDA	93.69 ± 0.34	0.70 ± 0.01	10.84 ± 0.18	12.59
TOX 18447/ Dunyo	94.55 ± 0.37	0.36 ± 0.00	10.42 ± 0.15	11.62
Adaesi/ AD	98.55 ± 0.05	0.08 ± 0.01	8.26 ± 0.12	7.08
Perfumed/ AD	96.36 ± 0.15	0.46 ± 0.01	9.55 ± 0.11	9.62
Perfumed/ Edenic	95.81 ± 0.18	0.22 ± 0.02	9.89 ± 0.09	10.27
Perfumed/ Otthofio	95.75 ± 0.21	0.32 ± 0.01	9.96 ± 0.18	10.36
Perfumed/ IDA	95.21 ± 0.03	0.48 ± 0.02	9.54 ± 0.12	10.62

Sources of the samples were also found to significantly affect ($p < 0.05$) yellowness of raw milled rice samples. Lightness and redness however, were not significantly affected by the sources of the samples. The effect of source on yellowness could be due to both pre- and post-harvest management factors such as drying and degree of milling. Studies by Dillahunty *et al.* (2001) indicated that high temperature and long exposure durations during drying cause yellowing or sun burn of rice grains.

Comparison of the total colour difference (ΔE) of the varieties was also investigated (Table 30). The mean L*, a*, and b* values recorded were used for the calculation of the total colour difference (ΔE). Observations of the total colour difference indicated wide variations ranging from 7.08 to 17.03 for Adaesi and Viwonor varieties respectively. The total colour difference is the single colour function of the Hunter tristimulus factors indicating that Adaesi is the brightest in colour followed by the TOX 3107 variety, perfumed rice samples and TOX 18447 respectively. Viwonor had the least level of brightness.

Analysis of variance on the total colour difference data showed significant differences in the varieties ($p < 0.05$). The sources of the samples were however, found not to have affected the total colour difference of the samples.

4.2.2.7 Sensory Analysis

The colour and translucency of raw milled rice was evaluated by sensory analysis. The samples were divided into 4 sets. Set 1 was made up of Bouake 189 and WITA 9 samples, set 2 of TOX 3107 and perfumed rice samples from Edenic mills, Afife, Otthofio foods, Dawhenya and IDA mills, Ashaiman. Set 3 was made up of Viwonor, Emo korkor and Adaesi samples while set 4 comprised TOX 3107 from UGARS, Kpong, TOX 3108 from IDA mills, Ashaiman, TOX 18447 from Dunyo farms, Afife and perfumed rice sample from Agro Deal Ghana Ltd, Hohoe.

Colour and translucency were significantly affected by variety ($p < 0.05$) for all the 4 sets of rice samples. Multiple range analysis indicated that there were statistically significant variations in colour and translucency of Bouake 189 and WITA 9; TOX 3107 and perfumed rice samples from Edenic mills, Afife, Otthofio foods, Dawhenya and IDA mills, Ashaiman and also in the varieties in set 3 and 4.

WITA 9, TOX 3107 and Adaesi varieties were found to be whiter and more vitreous than Bouake 189, perfumed and Emo korkor and Viwonor respectively. The ANOVA results are shown at Appendix 10.

Three out of the four sets of samples evaluated exhibited significant differences ($p < 0.05$) in intensities of colour and translucency due to the source of the samples. These variations in colour and translucency could be attributed to different pre- and post-harvest conditions/ handling of the grains such as temperature during ripening and drying as well as degree of milling.

The result (colour) of sensory analysis is a confirmation of results of objective colour measurement. Sensory analysis results confirm that Adaesi is the lightest in colour (whitest) and viwonor, the darkest (grey/ rosy).

4.2.3 Chemical Properties of Raw Milled Rice

4.2.3.1 Degree of Milling

This is the measure of the extent to which the bran layers and germ have been removed from the rice endosperm. In general, there are four degrees of milling: well milled, reasonably well milled, lightly milled and under milled (USDA, 1976). These descriptions are however, nebulous, as there is no precise definition for them.

Dye staining to emphasize the residual bran removal for easier visual observations was done. The observations are recorded in Appendix 11. The visual observations (Fig 12) indicated that Adaesi, perfumed rice from Agro Deal Ghana Ltd and TOX 3107 from the UGARS, Kpong had the highest degree of milling and can be classified as well milled rice since they were very close to the reference sample (R) (Fig. 12). The presence of green patches on the surface of some of the samples indicates that the outer bran layer has not been completely removed.

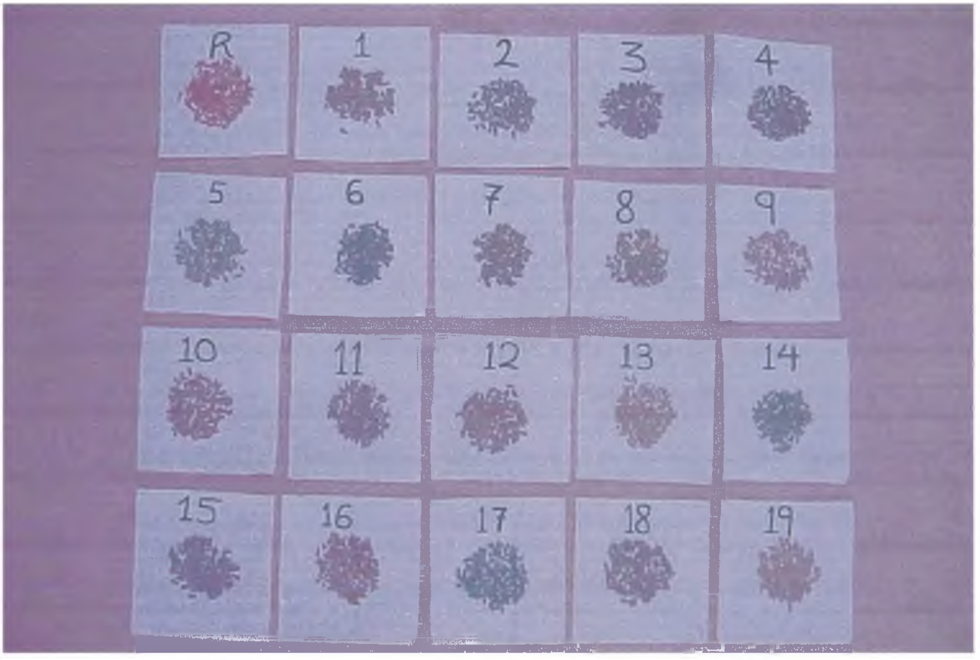
It can also be seen from the results that Agro Deal Ghana Ltd processed rice of the highest degree of milling (Adaesi and perfumed) followed by the UGARS, Kpong mills, and then IDA mills, Ashaiman (TOX 3107). The lower degree of milling observed in Viwonor can be attributed to the variety rather than the source or milling machine as bran removal was carried out twice in Viwonor. Thus the bran is tightly held to the endosperm of Viwonor hence higher force or setting may be required to fully remove bran layers in Viwonor.

Samples from Zorko rice mills, Kade; Edenic mills, Afife; and IDA mills, Ashaiman (Bouake 189) could be classified as reasonably well milled. TOX 3107 and perfumed rice samples (Otthofio foods, Dawhenya), Emo korkor (UG/ JICA, Kade), WITA 9 and Bouake 189 (KIP, Asutsuare) and Bouake 189 (Goku Industries, Akuse) and TOX 18447 (Dunyo farms, Afife) are lightly milled while Viwonor (Agro Deal Ghana Ltd, Hohoe); TOX 3108, WITA 9 and perfumed samples from IDA mills, Ashaiman could be classified as under milled as they had high proportion of outer bran layer on the milled kernels.

Well-milled rice with little or no bran adhering to the endosperm is generally preferred by majority of consumers- though well-milled rice has decreased nutrient value. Rice with lower degree of milling however is more nutritious since the proteins, fats, vitamins and minerals concentrated in the germ and outer layer of the starchy endosperm are consumed. The production of rice with lower degrees of milling is therefore nutritionally beneficial to consumers. However, lower degree milled rice is more susceptible to enzyme attack and become rancid faster due to high surface lipid. Thus lower degree milled rice samples will have shorter storage durations, unless kept under well-controlled temperature and relative humidity conditions. Fortunately, most of the rice milled in the study area is consumed soon after milling. Only 13.4 % of middlemen said they store milled rice. Bran remaining on the rice also affects the taste. Milling rice very hard improves whiteness and flavour.

Fig. 12. **Degree of Raw Rice Milling by Dye Staining**

Legend Code	**Sample**	**Source**
R	Reference sample	Market
1	Bouake 189	IDA Mill, Ashaiman
2	Bouake 189	KIP, Asutsuare
3	Bouake 189	Goku Industries. Akuse
4	Viwonor	Agro Deal Ghana Ltd, Hohoe
5	WITA 9	KIP, Asutsuare
6	WITA 9	IDA, Asutsuare
7	Emo korkor	UG/ JICA, Kade
8	Emo korkor	Zorko Mill, Kade
9	TOX 3107	UGARS, Kpong
10	TOX 3107	Edenic Mill, Afife
11	TOX 3107	Othoffio Foods, Dawhenya
12	TOX 3107	IDA Mills, Ashaiman
13	Adaesi	Agro Deal Ghana Ltd, Hohoe
14	TOX 3108	IDA Mills, Ashaiman
15	TOX 18447	Dunyo Farms, Afife
16	Perfumed	Edenic Mills, Afife
17	Perfumed	IDA Mills, Ashaiman
18	Perfumed	Otthofio Foods, Dawhenya
19	Perfumed	Agro Deal Ghana Ltd, Hohoe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4.2.3.2 Protein

The results of mean protein content obtained on dry matter basis (Table 31) ranged from 6.43 to 10.42 %. Most of the values are.comparable to literature values (Juliano, 1985b; Eggum *et al.*, 1982; and Pendersen and Eggum, 1983), which range from 7.33- 8.26 % (dry matter basis). Some of the samples have relatively higher values than literature values.

Statistical analysis indicates that protein content of the samples are significantly different among the varieties and sources ($p < 0.05$) (Appendix 12).

Since the bran has the highest protein content, the degree of rice milling has effect on protein content. From the results, Adaesi, the sample with the highest degree of milling had the lowest protein content while TOX 3108 with a relatively low degree of milling recorded the highest percentage protein.

Environmental factors are known to affect the composition of the rice grain (Juliano, 1985b). Protein content tends to increase with soil type, wider spacing or in borders and in response to high N fertilizer application, especially at flowering. Short growth duration, ambient temperature and cloudy weather during grain development, as occurs in the wet season may also increase protein contents. Mineral nutrition also affects the protein content of the rice grain (Huang, 1990). Thus any one or combinations of the above factors could influence the results.

A study by Villareal *et al.*, (1990) on eight varieties of rice grown in Cote d'Ivoire indicates that upland culture has a variable effect on protein content. The upland varieties in this study, Emo korkor and Viwonor had protein contents of 8.50 and 7.53 % respectively. Thus the protein content of 68.4 % of the samples was within protein contents of literature while 31.6 % were higher than literature values.

Protein content of imported rice samples from Thai, Viet Nam and the United States of America for comparison was between 7.50-7.67 % (dry matter basis). This indicates that most of the rice grown and milled in Ghana had higher protein content than the imported varieties on the Ghanaian market. This indicates that locally grown and milled rice is of good nutritional value as nutritional value of rice is mainly determined by the milled rice protein content. Rice with less protein however, tastes better.

4.2.3.3 Crude Fat

The results of percentage fat in the rice samples are shown in Table 31. This ranged from 0.1 to 1.6 %. Fifty percent of the samples had fat content within literature range (Juliano, 1985b; Eggum *et al.*, 1982; and Pendersen and Eggum, 1983) whereas 50 % recorded higher fat contents. Since fat is mainly in the bran, higher levels of percentage fat observed could be attributed to lower degrees of rice milling (Appendix 11). Imported rice samples from Thailand, Viet Nam and the United States (US No.5) analysed for comparison with Ghanaian grown and milled rice had fat content of 0.72, 0.80 and 1.16 % respectively. The higher fat content makes the samples more susceptible to rancidity due to lipase activity on the oil, which creates free fatty acids.

Statistical analysis showed significant difference in fat content ($p < 0.05$) among the varieties and sources (mills) (Appendix 13).

Table 31. Protein, Crude Fat and Crude Ash Composition of Rice Samples *

Variety	Mill	Protein (%) (N × 5.95)	Fat (%)	Ash (%)
Bouake 189	IDA, Ashaiman	7.50	0.99	0.64
Bouake 189	KIP, Asutsuare	6.98	0.75	0.38
Bouake 189	Goku, Akuse	8.08	0.11	0.58
Viwonor	Agro Deal, Hohoe	7.32	1.56	0.44
WITA 9	KIP, Asutsuare	7.32	1.03	0.45
WITA 9	IDA, Ashaiman	7.53	1.23	0.52
Emo korkor	UG/ JICA, Kade	8.50	0.40	0.27
Emo korkor	Zorko, Kade	8.38	0.39	0.33
TOX 3107	UGARS, Kpong	7.98	1.25	0.46
TOX 3107	Edenic, Afife	10.05	1.10	0.24
TOX 3107	Otthofio Foods, Dawhenya	6.43	0.57	0.34
TOX 3107	IDA, Ashaiman	7.52	0.93	0.26
TOX 3108	IDA, Ashaiman	10.42	1.30	0.79
TOX 18447	Dunyo farms, Afife	8.32	0.58	0.37
Adaesi	Agro Deal, Hohoe	6.45	0.95	0.37
Perfumed	Agro Deal, Hohoe	7.16	0.46	0.35
Perfumed	Edenic, Afife	8.19	0.35	0.32
Perfumed	Otthofio Foods, Dawhenya	8.55	0.36	0.47
Perfumed	IDA, Ashaiman	8.18	0.53	0.55

* - Results on dry matter basis

4.2.3.4 Ash

The minerals are concentrated in the outer layers of brown rice or in the bran fraction. The mean percentage crude ash (dry matter basis) observed (Table 31) ranged between 0.24 and 0.79 % for TOX 3107 from Edenic mills, Afife and TOX 3108 from IDA mills, Ashaiman, respectively. These values compare favourably with results of other researchers (Juliano, 1985b; Eggum *et al.*, 1982; and Pendersen and Eggum, 1983). Statistical analysis of crude ash content showed very significant differences ($p < 0.05$) between the samples (Appendix 14). The significant differences between the samples from different sources could be attributed to variations in the degree of milling of rice samples and probably, pre-harvest conditions of rice. The mineral content of the rice grain is also affected (Kitagishi and Yamane, 1981) by the mineral content of the soil and irrigation water.

Samples of imported rice bought from the market for comparison contained 0.33–0.66 % ash. These values are similar to percentage ash values of locally milled rice.

The mineral content of Emo korkor, Adaesi, Viwonor and three imported rice varieties are shown in Table 32. The results indicate that the mineral contents of the 3 local rice varieties are higher than the imported samples. The very high phosphorus levels of local rice samples confirm the lower degree of milling of the local rice samples. Analysis of variance showed significant differences ($p < 0.05$) in mineral content between the local and imported samples (Appendix 15). The higher level of minerals in local rice indicates a better nutritional quality of Emo korkor, Adaesi and Viwonor compared with the imported samples.

Table 32. Mineral Composition of Some Rice Varieties*

Sample	Mineral content mg/100g					
	Calcium	Iron	Magnesium	Zinc	Copper	Phosphorus
Emo korkor	55.2	358.0	216.8	50.2	9.1	970.1
Adaesi	22.6	257.2	259.4	49.6	6.8	1221.9
Viwonor	29.1	318.2	325.0	47.4	6.8	1373.1
Thai (Diamond)	59.5	63.9	89.0	0	6.8	0
Vietnamese	88.3	62.8	111.6	0	9.3	4.6
US No.5	91.5	82.1	307.8	0	9.1	16.0

*- Results on dry matter basis

4.2.4 Functional Properties of Rice

4.2.4.1 Alkali Spreading Value

Alkali spreading value, an indicator of gelatinisation temperature was measured in terms of extent of disintegration of whole-kernel milled rice in contact with dilute alkali. The results of the analysis (Table 33) show that the grains have alkali spreading values of 2-6. Alkali spreading values correspond to gelatinisation temperature (GT) as follows: 1-2 = high (74.5-80°C); 3=high intermediate; 4-5=intermediate (70-74°C); and 6-7=low (55-70°C). Thus Viwonor showed characteristics of high GT class. Bouake 189, WITA 9 and Adaesi varieties exhibited characteristics of high intermediate GT class. TOX 3108 and Emo korkor have GT of 70-74°C while TOX 18447 can be classified as having low GT value.

TOX 3107 variety showed characteristics of GT classes of 2-4 from the various sources while the perfumed rice samples can be classified as intermediate (sample from IDA) or low GT samples. The differences observed in the GT classes of the same variety of rice from different sources could be attributed to pre-harvest conditions. It has been observed that low ambient temperature during ripening may independently reduce GT (Nikuni *et al.*, 1969; Resurreccion, *et al.*, 1977; Dien *et al.*, 1987).

The GT affects the degree of cooking of rice because of the cooking gradient from the surface to the core of the grain. Because GT correlates directly with cooking time, low GT samples cook faster. Thus TOX 18447 may be the fastest to cook and Viwonor, the longest.

4.2.4.2 Apparent Amylose Content

The amylose content of the rice starch is the major eating quality factor. It correlates directly with volume expansion and water absorption during cooking, and with hardness, whiteness and with dullness of cooked rice (Juliano, 1985b).

The result of apparent amylose content of the rice samples is given in Table 34. The results indicated that all the varieties, except TOX 3108 and perfumed rice samples are characterized by high amylose contents while TOX 3108 has very low amylose content.

Table 33. Alkali Spreading Value of Raw Milled Rice

Variety	Mill	Spreading value	Gelatinisation class
Bouake 189	IDA, Ashaiman	3	High intermediate
Bouake 189	KIP, Asutsuare	2	High
Bouake 189	Goku, Akuse	3	High intermediate
Viwonor	Agro Deal, Hohoe	2	High
WITA 9	KIP, Asutsuare	3	High intermediate
WITA 9	IDA, Ashaiman	3	High intermediate
Emo korkor	UG/ JICA, Kade	5	Intermediate
Emo korkor	Zorko, Kade	5	Intermediate
TOX 3107	UGARS, Kpong	3	High intermediate
TOX 3107	Edenic, Afife	2	High
TOX 3107	Otthofio Foods, Dawhenya	4	Intermediate
TOX 3107	IDA, Ashaiman	3	High intermediate
TOX 3108	IDA, Ashaiman	4	Intermediate
TOX 18447	Dunyo farms, Afife	6	Low
Adaesi	Agro Deal, Hohoe	3	High intermediate
Perfumed	Agro Deal, Hohoe	6	Low
Perfumed	Edenic, Afife	6	Low
Perfumed	Otthofio Foods, Dawhenya	6	Low
Perfumed	IDA, Ashaiman	3	High intermediate

Three out of the 4 perfumed rice samples were characterised by low amylose content. Rice with low amylose content cooks soft and sticky hence suitable for 'Motuo', rice porridge and 'Waakye' while rice with high amylose content cooks firm and fluffy (Juliano, 1985b). Typically, US long-grain cultivars cook dry and fluffy with grains remaining separate and are characterized as having relatively high amylose content. Medium and short US cultivars are generally moist, chewy and clingy after cooking and have comparatively low amylose contents (Webb, 1985). In comparison with US cultivars, all the varieties except TOX 3108 can be classified as long grain while TOX 3108 and 3 samples of perfumed rice can be classified as medium grain types.

However, differences in eating quality also exist among varieties of similar amylose content, which are related to other quality factors, such as final gelatinisation temperature and gel consistency. Hard gel consistency gives harder cooked rice and has a very high amylograph setback. Thus among the high amylose samples, Adaesi and Viwonor may give harder cooked rice since they recorded the highest gel consistency and setback viscosities respectively.

Juliano and Villareal (1991) indicated that of the varieties of rice grown in Ghana, high amylose rice predominates. The result of this study therefore in confirms the observations of Juliano and Villareal (1991).

Amylose content is an inherited property of starch. Thus, the difference in the amylose content of the perfumed rice samples could mean that the perfumed rice samples are not of the same cultivar or variety.

Table 34. **Apparent Amylose Content of Rice**

Variety	Mill	Amylose content (%) *	Amylose type
Bouake 189	IDA, Ashaiman	30.06	High
Bouake 189	KIP, Asutsuare	29.26	High
Bouake 189	Goku, Akuse	31.60	High
Viwonor	Agro Deal, Hohoe	30.50	High
WITA 9	KIP, Asutsuare	30.09	High
WITA 9	IDA, Ashaiman	28.39	High
Emo korkor	UG/ JICA, Kade	31.95	High
Emo korkor	Zorko, Kade	28.48	High
TOX 3107	UGARS, Kpong	27.75	High
TOX 3107	Edenic, Afife	28.85	High
TOX 3107	Otthofio Foods, Dawhenya	29.65	High
TOX 3107	IDA, Ashaiman	27.30	High
TOX 3108	IDA, Ashaiman	10.36	Very low
TOX 18447	Dunyo farms, Afife	26.66	High
Adaesi	Agro Deal, Hohoe	29.48	High
Perfumed	Agro Deal, Hohoe	16.99	Low
Perfumed	Edenic, Afife	15.01	Low
Perfumed	Otthofio Foods, Dawhenya	25.60	High
Perfumed	IDA, Ashaiman	16.09	Low

*- Percentage amylose, milled rice dry weight basis

4.2.4.3 Amylographic Cooked Paste Viscosity

Among the important practical properties of starch is its ability to swell and yield viscous paste when water suspensions of the granules are subjected to heating above the gelatinisation temperature. The swelling of the granules and their subsequent disintegration on prolonged heating lead to significant changes in the viscosity and other rheological properties of the paste which are characteristic of a particular starch. The basis of the gelatinisation is the absence of shear and at high moisture due to the hydration property of native starch at high temperature.

Brabender Viscoamylograph presents useful information on the hot and cold paste viscosity characteristics of starch based foods. Amylograph provides an insight into the textural changes of rice during cooking.

Pasting temperature indicates the temperature at which the first detectable viscosity is measured by the amylograph. This gelatinisation is characterised by water-mediated disruption of the molecular orders within a starch granule during heating, manifested in granular swelling, native crystalline melting, loss of birefringence and starch solubilization (Atwell *et al.*, 1988). From the results (Table 35), TOX 3108 recorded the highest pasting temperature of 82.6°C, followed by Bouake 189 (81.5-81.7°C) and Viwonor (80.8°C). The perfumed rice samples recorded similar pasting temperature of 76.0-77.5°C. TOX 3107 variety recorded a wider variation in pasting temperature (76.7-81.6°C). TOX 18447 recorded the lowest pasting temperature of 62.3°C. Samples with lower pasting temperature will be easier to cook and would require less heat for

Table 35. **Amylographic Cooked Paste Viscosity of Rice Samples**

Variety	Mill	Pasting temperature (°C)	Peak viscosity (BU)	Viscosity at 95°C (BU)	Viscosity at 95°C Hold (BU)	Viscosity at 50°C (BU)	Viscosity at 50°C (BU)
Bouake 189	IDA, Ashaiman	81.6	815	315	355	755	750
Bouake 189	KIP, Asutsuare	81.5	815	370	410	785	790
Bouake 189	Goku, Akuse	81.7	810	335	400	805	765
Viwonor	Agro Deal, Hohoe	80.8	1000	365	490	860	1000
WITA 9	KIP, Asutsuare	75.9	992	585	570	992	992
WITA 9	IDA, Ashaiman	80.0	995	540	540	990	995
Emo korkor	UG/ JICA, Kade	78.5	760	300	370	720	748
Emo korkor	Zorko, Kade	75.2	830	340	380	810	775
TOX 3107	UGARS, Kpong	77.5	1080	275	380	1040	1068
TOX 3107	Edenic, Afife	80.5	905	250	385	840	765
TOX 3107	Otthofio Foods	76.7	900	270	385	880	885
TOX 3107	IDA, Ashaiman	81.6	1000	440	575	1000	1000
TOX 3108	IDA, Ashaiman	82.6	830	320	400	800	790
TOX 18447	Dunyo farms, Afife	62.3	990	425	520	980	950
Adaesi	Agro Deal	74.5	1165	440	480	1120	1160
Perfumed	Agro Deal	77.5	800	470	475	780	775
Perfumed	Edenic, Afife	76.4	850	540	600	840	805
Perfumed	Otthofio Foods	76.0	950	480	505	930	890
Perfumed	IDA	76.7	865	415	460	860	815

gelatinisation to start than higher pasting temperature varieties. Thus requirement of heat for cooking the various varieties will follow the order:

TOX 18447 < Adaesi < Perfumed < Emo korkor < WITA 9 < TOX 3107 < Viwonor < Bouake 189 < TOX 3108.

All the varieties except TOX 18447 has gelling temperatures indicative of long grain types.

Peak viscosity is linked with the ease of cooking the products and it is a measure of the highest value of viscosity attained by the slurry during the heating cycle (25-95°C). Amylograph pasting characteristics of typical long grain rice usually show an intermediate peak viscosity (700-900 BU) and a relatively high viscosity (750-950 BU) of the cooked paste in cooling to 50°C. The Bouake 189 and 3 of the perfumed rice samples, Emo korkor, TOX 3108 and the TOX 3107 from Otthofio foods, Dawhenya, showed peak viscosities of 760-900 BU (Table 35) indicative of long grain types. Adaesi recorded the highest peak viscosity of 1165 BU.

The viscosity attained by a sample after holding at 95°C for 30 minutes gave an indication of the ease of breakdown of the cooked pastes. This illustrates the stability of the paste during cooking. In this study, the viscosity of all the varieties except WITA 9 increased. The viscosity of one of the WITA 9 samples remained the same throughout the 30 minutes period while the viscosity of the other decreased slightly. This implies that the cooked paste of all the varieties can better withstand shear at high temperature during cooking except WITA 9, which exhibited less cooked paste stability. WITA 9 had the highest viscosity at 95°C.

The increase in viscosities of the pastes of the rice samples during the cooling cycle (Fig. 13) is probably due to the gelatinisation and subsequent swelling of the starch granules of rice as the elements present in the hot paste (swollen granules, fragment of swollen granules, colloidally and molecularly dispersed starch molecules) begin to associate or retrograde as the temperature of the paste decreases (Whistler *et al.,* 1984).

The viscosity after cooling to 50°C reflects the retrogradation tendency or setback viscosity of the cooked pastes. At this stage, there is the reassociation of the molecules of gelatinised starch to form ordered crystalline structure.

Typical long grain rice has viscosity of 750-950 BU at 50°C while medium and short grain rice samples have viscosities of 650-750 BU at 50°C. From the study, the perfumed rice samples, TOX 3108, Viwonor, and Bouake 189 varieties had cooled paste viscosity between 750-950 BU indicative of long-grain varieties while Adaesi, TOX 18447, WITA 9 and samples of TOX 3107 recorded cooled paste viscosities of 980-1120 BU. Two samples of TOX 3107 and a sample of Emo korkor had cooled paste viscosities indicative of long grain rice while the other Emo korkor sample recorded cooled paste viscosity of 720 BU indicating a medium or short grain type.

The cooled paste property of starch is of considerable importance to the food processor as it is an indication of thickening produced, setback due to aggregation and retrogradation tendency of amylose content. Also, setback values appear to be useful in predicting the degree of stickiness of cooked rice.

Table 36. **Consistency, Breakdown and Setback Viscosities of Rice**

Variety	Mill	Viscosity (BU)		
		Breakdown (Peak – 95°C Hold)	Setback (50°C – Peak)	Consistency (50°C - 95°C Hold)
Bouake 189	IDA, Ashaiman	460	-60	400
Bouake 189	KIP, Asutsuare	405	-30	375
Bouake 189	Goku, Akuse	410	-5	405
Viwonor	Agro Deal, Hohoe	510	-140	370
WITA 9	KIP, Asutsuare	422	0	422
WITA 9	IDA, Ashaiman	455	-5	450
Emo korkor	UG/ JICA, Kade	390	-40	350
Emo korkor	Zorko, Kade	450	-20	430
TOX 3107	UGARS, Kpong	700	-40	660
TOX 3107	Edenic, Afife	520	-65	455
TOX 3107	Otthofio Foods, Dawhenya	515	-20	495
TOX 3107	IDA, Ashaiman	425	0	425
TOX 3108	IDA, Ashaiman	430	-30	400
TOX 18447	Dunyo farms, Afife	470	-10	460
Adaesi	Agro Deal	685	-45	640
Perfumed	Agro Deal	325	-20	305
Perfumed	Edenic, Afife	150	-10	240
Perfumed	Otthofio Foods	445	-20	425
Perfumed	IDA, Ashaiman	405	-5	400

The viscosities of the pastes were measured after keeping the temperature constant at 50°C for 20 minutes (50°C Hold). This reflects the stability of the paste as it might be used. It is an indication of the consistency (Table 36) at which the gruel will most likely be eaten. Adaesi recorded the highest viscosity at this stage.

Viscosity curves are routinely used to indicate the cooking quality of rice (Blakeney *et al.*, 1994; Okadome *et al.*, 1998). From the viscosity curves (Fig. 13), it will be seen that the shape of all the varieties do not vary significantly but the height of the curves vary. The higher height of WITA 9 samples compared with Bouake 189 samples (Fig. 13A) indicates that Bouake 189 samples are softer than WITA 9 while TOX 3108 is softer than the other TOX varieties (Fig 13B). Billiaderis and Juliano (1993) showed that rate of increase in gel rigidity and starch retrogradation is affected by cultivar. Perez *et al.*, 1993; Lu *et al.*, 1997 and Villareal *et al.*, 1997 also indicated that cultivar affects the rate of retrogradation, which may be due to differences in molecular properties of the amylopectin from each cultivar. This could explain the variations in the height of the amylograph curves of all the varieties.

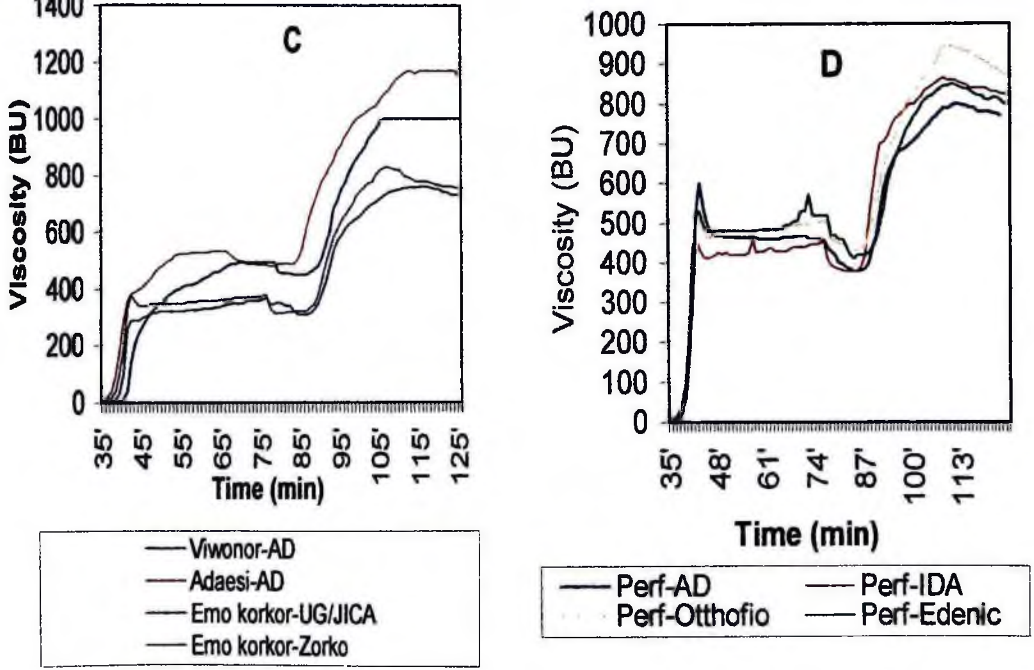
Fig 13. Amylographic Cooked Paste Viscosity of Rice Samples

A – Bouake 189 and WITA 9 samples

B – TOX varieties

C – Local varieties

D – Perfumed rice samples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Time (min)
Viwonor-AD
Adaesi-AD
Emo korkor-UG/JICA
Emo korkor-Zorko
D
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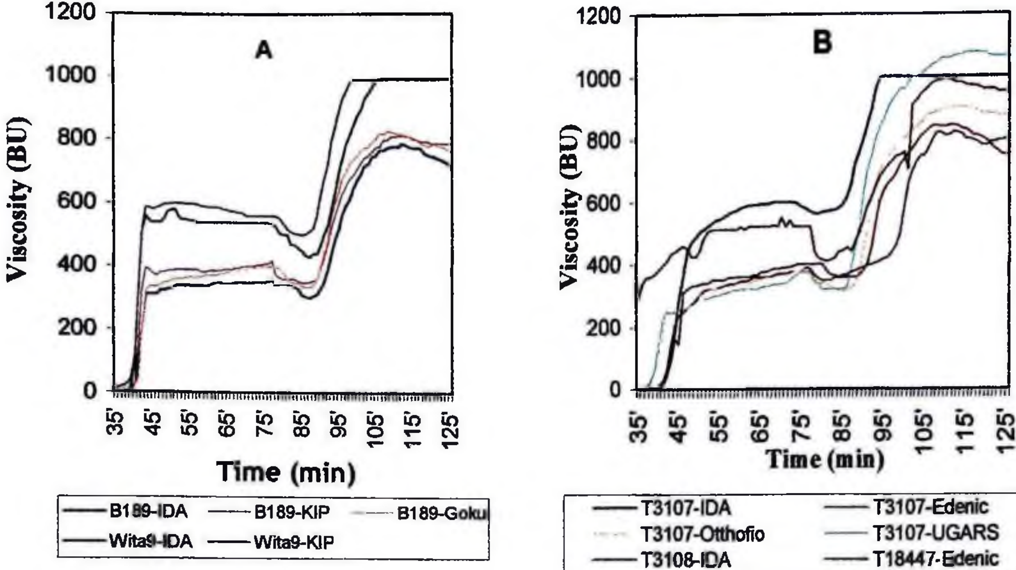
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125'
B189-IDA
B189-KIP
B189-Goku
Wita9-IDA
Wita9-KIP
T3107-IDA
T3107-Edenic
T3107-Otthofio
T3107-UGARS
T3108-IDA
T18447-Edenic

4.2.4.4 Water Absorption Capacity

The water absorption at room temperature (27°C) ranged between 85.67mg/ 100g for Adaesi to 105.19mg/ 100g for TOX 3108. The variations in the water absorption capacity at room temperature could be influenced by the degree of milling the samples, and hence protein content. Adaesi and TOX 3108 with the lowest and highest water absorption capacity respectively, also contained the lowest and highest percentage protein respectively.

The water absorption capacity at 70°C of all the samples was higher than at 27°C. This is because starch imbibes more water at higher temperatures.

5 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Post-harvest activities are carried out manually and this results in quantitative and qualitative losses during each processing step. Farmers do not have appropriate means of removing high-density foreign materials from paddy hence paddy usually have stones in them. Paddy is sun-dried by all farmers hence temperature and relative humidity of drying environment is not controlled. This is likely to have adverse effect on milling quality and yield. Moisture content is not objectively measured. Paddy rice is stored in sacks and traditional cribs for various durations- up to a year. Seed is obtained from University of Ghana Agricultural Research Stations, extension officers of the Ministry of Food and Agriculture, Irrigation Projects, and from other farmers. The problems faced in rice farming include lack of machinery, high cost of inputs, weather fluctuation and quantitative losses.

Rice is sold in the form of paddy and raw milled. Rice sold is neither branded nor graded. Rice grown in the study area passes mainly through individual middlemen. Most farmers sell off their paddy by the forth month after harvest. Most milled rice is sold immediately after milling.

Milled rice is sold mainly on the market in small units. There is very little packaging of rice milled in Ghana. The main problem in rice marketing is lack of ready market for the produce hence, rice marketing is characterized by marketing on credit. Middlemen mainly dictate price of paddy and milled rice.

Small-scale operators, who have not had any formal training in the use and adjustment of mills, process most of the rice produced. It also appears that millers do not have access to information on how to go about improving their methods and outputs. This can affect rice quantity and quality. Most of the mills have purpose-built drying floors for drying paddy. A small room adjacent to the milling room or the milling room itself is used for paddy and milled rice storage at mills, hence temperature and humidity conditions of storage room are not controlled. The storage rooms are made mainly of aluminium roofing sheets, cement walls and concrete floors.

Small- and medium-scale, single pass, rubber roller mills dominate in the study area. Most of the mills process rice on custom basis only, and produce under capacity. Total rice recovery rate of mills range between 45-75 %. Percentage recovery of head and broken kernels could however not be obtained from all the mills. Mills are maintained by greasing, replacing and repairing parts of the mill.

Most of the mills have pre-cleaning device that remove chaff. Most mills lack destoners and electromagnetic separators required in removing stones and ferrous materials respectively. Mills lack polishers for polishing rice after whitening and milled rice is not graded. Thus a number of improvements could be made to operating procedures. Frequent damage to sieves due to presence of stones, low head rice yield due to negative pre- and post-harvest handling of paddy, power fluctuations and seasonal production of paddy are the main problems faced in rice milling.

Rice samples worked on could be classified as long-, medium-, and short-grain types based on definitions of GS 61: 1990; Codex (1995) and FAO (1975). High moisture content of paddy rice during storage could make paddy rice susceptible to fungi attack. Low moisture content of raw milled rice could affect cooked rice texture. Milled rice samples could be classified as Ghana rice grade 1-3 based on extraneous matter content alone, grade 1-5 based on percentage discoloured grains alone, and grade 1 based on presence of chalky grains alone. The high percentage of broken kernels produced by mills renders Ghana rice poorer quality rice compared with both Ghana and International standards especially because mills do not grade rice.

The statistical difference in the varieties and sources of rice found in colour and translucency has been attributed to drying and storage conditions of rice as well as the degree of rice milling.

Protein, fat and ash content ranged between 6.45 to 10.45 %; 0.11 to 1.56 %; and 0.24 to 0.79 % respectively. Statistical differences found in percentage fat, ash and protein content were partly due to variations in the degree of rice milling. Most of the samples had low degrees of milling and higher nutritional content. Thus Ghana rice is nutritionally higher than imported rice varieties.

Rice grains exhibited alkali spreading values of 2 to 6 and were mostly high amylose varieties. TOX 3108 recorded the highest pasting temperature of 82.6°C whilst the lowest pasting temperature of 62.3°C was exhibited by TOX 18447. Rice samples showed peak viscosity of 760-1165 BU and relatively high viscosity (755-1040 BU) of the cooked paste in cooling to 50°C, except Emo korkor, which had cooled paste viscosity of 720 BU indicative of medium and short grain types.

Although rice size and shape of US rice are useful indicators of their quality characteristics, rice from the study area does not seem to be distinguishable by the same characteristics. Thus the rice varieties overlap in the properties of the 3-grain types.

5.2 RECOMMENDATIONS

Since any one or combinations of factors including genetic, and pre- and post-harvest handling affect rice quality, it is recommended that

1. Controlled study be carried out on the effect of harvest moisture content, threshing method, drying and storage temperature and relative humidity on head and total head rice yield of various rice varieties grown in Ghana
2. Study be carried out to find the critical moisture content (CMC) range for crack susceptibility for each rice variety as studies have shown varied effect of moisture content on various types and varieties of rice under different environmental conditions
3. Farmers should be encouraged to form Farmers' Associations so that they can benefit from government policies and educational programs from government and Non-Governmental Organisations.
4. The use of moisture metre in determining the moisture content of rice should be encouraged. Also, studies should be done on the methods of moisture content determinations carried out by farmers and middlemen to assess their suitability

and probable substitution for more objective methods such as the use of moisture meter. This is because the moisture content of rice is a critical factor affecting milling output.

5. Farmers and middlemen should be encouraged to use mechanical forms of processing rice, especially harvesting and threshing. This is because use of manual means does not promote large-scale farming
6. Rice millers should be given formal training on milling. This would improve rice quality
7. Millers should keep up-to-date records on milling operations so that milling efficiency and capacities can be measured quantitatively. This is the only way by which problems in the processes can be identified and hence rectified.
8. Millers should be encouraged to grade milled rice so as to promote the quality and hence consumption of locally milled rice.
9. Multistage polishing for removal of bran should be practiced to avoid high incidence of brokens due to excessive heating of grains in the polishing process. This will also result in the production of rice with more polished and translucent surface.
10. All the steps involved in the processing of rice should be studied in detail to determine their effect on rice breakage. This is essential as the high percentage of breakage observed makes local rice less attractive.
11.

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APPENDICES

Appendix 1: Questionnaire for rice farmers

EVALUATION OF RICE MILLING AND QUALITY OF RICE IN GHANA

QUESTIONNAIRE FOR RICE FARMERS

Questionnaire No. .... Date:..

A. **RESPONDENT DEMOGRAPHIC DATA**

1. Town/Village:..

2. Age: 1=<20 2 = 20-29 3 = 30 – 39 4=40–49 5= >50

3. Gender 1 = Male 2= Female

4. Educational level: 1= None 2= Elementary 3=Secondary
4=Tertiary
5= Non-formal 6 = Other (specify): ....

5. Major occupation...

B. **PRODUCTION & MARKETING**

6. Number of years in rice production...

7. What is the source of rice (seed) for planting? ....

8. What times of the year do you plant rice ....

9. Type of rice farming 1= irrigation 2=upland 3=inland valley 4=lowland

10. What variety(s) of rice do you cultivate? ....

11. Are there other varieties of rice that are not grown? 1=yes 2=no

12. If yes, name and indicate why they are not grown ....
....

14. Who buys rice from you and in what form do you sell the rice?..
....

15. How soon do you sell off rice after harvesting? ... .

C. HARVESTING

16. Is the rice field drained prior to harvesting? 1=yes 2=no

17. Describe the process ....
....
....

18. How soon do you harvest rice after draining the soil surface water? ....

19. What factors do you consider prior to fixing a date for the draining ....
....
....

20. How is rice harvested? 1 = Hand harvesting 2= Mechanical

21. What tool(s) do you use in rice harvesting? 1 = Combine harvester 2= Sickle
3 = Knife 4- Kubota harvester 5 = Other (specify)..............................

22. How do you know it is time to harvest rice? ....
....

23. After harvesting, do you keep the different varieties of rice together or separate?

1= separate 2= together

24. Do you think that the method and equipment you use in rice harvesting have any effect on the milling yield and quality? 1= Yes 2 = No

25. State the effect, if any ....
....

D. THRESHING

26. How is the harvested rice threshed? 1 = Combine harvester
2 = Tractor 3 = Sticks on clay floor 4 = Sticks on tarpaulin

5 = Sticks on concrete floor 6 = Shallow pit, beat with sticks
7= other (specify) ....

27. Is there any problem with the method of threshing you use? ....
....

E. CLEANING

28. Is the paddy cleaned after threshing? 1=Always 2=Sometimes 3=Never

29. How is the cleaning done? 1= Winnowing 2 = Mechanical aspirator

3 = other specify ....

F. DRYING

30. Is the paddy dried before milling? 1 = Yes2 = No

31. How soon is the rice dried after harvesting? ....

32. How is the paddy dried? 1 = Sun drying 2 = Controlled atmosphere drying

33. If sun drying is done, do you stir rice during drying? 1 = Yes 2 = No

34. Specify artificial drying type if used ....

35. At what temperature is rice dried? ....

G. STORAGE

36. Is paddy stored before milling? 1 = Yes 2 = No

37. What storage facilities do you use? 1 = in bags 2 = traditional cribs
3 = heaped on floors 4 = other (specify)..

38. How long is the paddy stored before milling? 1 = <2 weeks
2=2 weeks-I month 3 = 1-2 months 4 = 2-5 months 5 = >5 months

39. At what temperature is the rice stored? ....

40. At what moisture content is rice stored? ....

41. What problems do you have with growing and selling of rice? ....

Appendix 2: Questionnaire for Rice Millers

EVALUATION OF RICE MILLING AND QUALITY OF RICE IN GHANA
QUESTIONNAIRE FOR RICE MILLERS

Questionnaire No. .... Date: ....

A. RESPONDENT DEMOGRAPHIC DATA

1. Name of mill .... 2.Location. ....

3. Total number of employees: ....

4. Educational level of mill operators: 1=none 2=Elementary 3=Secondary
4=Tertiary 5=Non-formal 6=other (specify) ....

5. Operating period per day .... per annum ....

6. How much (volume) rice do you handle in a day? ....

B. DRYING AND STORAGE

7. Do you have facility for drying rice prior to milling? 1 = yes 2 = No

8. What is the capacity of the drying facility...

9. Do you have storage facility? 1 = Yes 2 = No

10. What is the storage capacity? ....

11. What is the store made of?

Floor	Wall	Roof
1 = Concrete	1 = cement blocks	1= aluminum roofing sheets
2 = wood	2 = wood	2 = roofing tiles
3 = clay	3 = clay/bricks	3 = Thatch
4 = other (specify)	4 = other specify	4 = other specify ....

12. How long is rice (paddy) kept in the store at the mill before milling?
1 = 1- 6 hours 2 = 6 hours-24 hours 3= 2-7 days 4 = 1-2 weeks
5 = > 2 weeks

13. At what temperature is the rice kept at the mill before milling?.....................

14. Is milled rice stored at the mill? 1 = yes 2 = no

15. If yes, how long? 1 = <5 hours 2=5 hours – 24 hours 3 = 24-48 hours
4 = > 48 hours.

C. PERFORMANCE OF RICE MILLS

16. Hulling capacity per day: maximum .... actual ....

17. Milling capacity per day: maximum .... actual ....

18. Milling overturns (recovery rates/yield)

(i) (I) whitening
Head rice
....
Broken rice .... second heads .... Screenings...... Brewers.........
Bran and flour ....hull...

- (II) Polishing
Heads .... broken rice.......... Flour............................

19. Do you enrich the rice in any way? 1 = yes 2 = No

20. If yes, state what is done ....
....
....

D. MAINTENANCE OF MILLS

21. Do you have facilities to undertake repair and maintenance work of the mill?
1 = Yes 2 = No

22. Do you have a maintenance schedule? If yes, describe. ....
....
....

23. How long have you been using the mill? ....

24. Have you changed any of the parts since you started using the mill? ....
....

E. TECHNICAL FEATURES OF RICE MILLS

25. Pre-cleaning device: 1 = yes, 2 = No; type ....

26. Aspirator: 1 = yes 2 = No Type:............................ Efficiency rate ......

27. Paddy separators: 1 = yes 2 = No Type:................................
Efficiency rate................................

28. Seed separators: 1 = yes 2 = No Type:....................................
Efficiency rate.....................

29. Destoners/Gravity separators: 1 = yes 2 = No; Type ....

Efficiency rate.....................

30. Length sizers 1 = yes, 2 = No 31. Diameter sizers 1 = yes, 2 = No

32. Weighing scale 1 = yes, 2 = No 33. Pearlers 1 = yes, 2 = No

34. Polishers 1=yes, 2 = No 35. Parboiling facility: 1 = yes 2 = No

36. Is there dust production during milling? 1 = yes 2 = No

37. Is there noise production during milling? 1 = yes 2 = No

38. Which of the following technologies do you use? 1 = small-scale steel huller

2 = small scale rubber rollers 3 = large-scale rubber rollers
4 =other (specify)..

39. Is/are there any problem(s) with the mill that you think affects the milling output and quality? (State them)..
....
....
....

40. What are the major problems faced in rice milling?
....
....
....

E. MARKETING

41. Who do you buy rice from and in what form is it obtained? ....
....

42. Who buys rice from you and in what form do you sell it? ....
....

Appendix 3: Questionnaire for Middlemen

EVALUATION OF RICE MILLING AND QUALITY OF RICE IN GHANA
QUESTIONNAIRE FOR MIDDLEMEN

Questionnaire No. ....Date...

A. RESPONDENT DEMOGRAPHIC DATA

1. Current residential location .... 2. Gender 1 = male 2 = female

3. Age: 1=< 20 2 = 20-29 3 = 30-39 4 = 40-49 5 = >50

4. Educational level: 1 = none 2 = Elementary 3 = Secondary 4 = Tertiary
5= Non-formal 6 = other (specify):..

B. PADDY

5. Where do you get your paddy (source)? ....
6. What varieties do you usually buy? ....

7. Why?
....
....

8. Are there some varieties you will usually not buy? (If yes, give reasons). ....
....
....

9. Do you dry paddy prior to milling? 1 = yes 2 = No

10. If yes, why? ....
....

11. How do you know the paddy is dried enough for milling? ....
....
....

12. Do you store paddy before milling? 1 = yes 2 = No

13. If yes, why ....

14. If yes, how long do you store paddy before milling? ....

15. What storage facility do you use? ....

C. MILLED RICE

16. Do you store rice after milling? 1 =yes 2 = No

17. If yes, why? ....
....
....

18. How is the milled rice stored? ....
....
....

19. What factors, in your opinion, affect the milling quality of rice? ....
....
....
....

D. RICE MARKETING

20. How do you package rice for marketing?...
....

21. What is the source of your packaging material?......................................
....

22. Where do you sell the milled rice and in what units?
1=on the market ....units 2=to wholesalers ....Units ......
3=other (specify).....................units

23. How soon do you sell rice after milling? ....

24. What do you consider a major problem in rice marketing?

Appendix 4: Ballot sheet for Sensory Analysis of Rice

RANKING THE COLOUR AND TRANSLUCENCY OF RAW MILLED RICE

Name:....................................... Date: ....

Instruction

You have been presented with 5 coded raw milled rice samples. Rank these samples for colour and translucency (read definition below if in doubt) by marking the relative intensity of each attribute of the coded rice samples on the horizontal line scale and label each vertical line with the corresponding sample code.

Colour

White Dark grey/rosy

Translucency

Bright and clear Chalky

Comments (optional): ....

....

Translucence: to shine through, permitting the passage of light, clear or transparent

Appendix 5: Types of rice milling machines (mills) used by mills

Rice mill	Milling machine used*
Edenic, Afife	Rice Machinery Supply corp., Florida, USA
Dunyo, Afife	Satake, model SMR, Satake Eng. Co. Ltd, Tokyo, Japan
UGARS, Kpong	PC; Satake Eng. Co. Ltd, Tokyo, Japan
IDA, Ashaiman	PC No. 286033; Satake Eng. Co. Ltd, Tokyo, Japan
Dunyo, Dawhenya	Satake Rice Machine; Satake Eng. Co. Ltd, Tokyo, Japan
Otthofio, Dawhenya	Satake Rice Machine, Satake Eng. Co. Ltd, Tokyo, Japan
Quality Grains, Aveyime	Marco Technology Corp., Miami, USA. Type: H-10 PHA
BB mills, Kade	Satake Rice Machine, Type SE, Satake Eng. Co. Ltd, Tokyo, Japan
Zorko, Kade	Satake Rice Machine, Satake Eng. Co. Ltd, Tokyo, Japan
UG/JICA, Kade	Satake Rice Machine; model BIOD, Type SR, Satake Eng. Co. Ltd, Tokyo, Japan
KIP, Asutsuare	YANMAR VHP 800
Station mill, Asutsuare	*
Aparfu Nettey, Asutsuare	*
Goku Industries, Akuse	*
Agro Deal, Hohoe	Rice milling unit, model 16990, Shan Dong Yu Tai, Machine building plant, China.
Kakpor, Hohoe	*

* - Type of mill not known

Appendix 6: Properties of paddy rice

Source	Dockage (%)	Moisture (%)
Farmer	0.28	16.70
Farmer	1.22	13.86
Mill	0.56	13.28
Farmer	1.17	14.71
Mill	0.43	13.70
Mill	1.91	13.40
Mill	0.44	13.42
Mill	0.30	12.42
Farmer	0.25	15.40
Farmer	0.39	12.88
Farmer	0.58	17.30
Farmer	1.64	15.60
Mill	0.37	13.81
Mill	0.45	13.41
Mill	1.13	13.51

Appendix 7: Uniformity in length and width of raw milled rice

Variety	Source	Length	Width
Bouake 189	IDA, Ashaiman	6.02	4.95
Bouake 189	KIP, Asutsuare	6.58	3.90
Bouake 189	Goku, Akuse	4.27	4.81
Viwonor	Agro Deal, Hohoe	5.36	6.68
WITA 9	KIP, Asutsuare	5.78	4.90
WITA 9	IDA, Ashaiman	5.16	6.54
Emo korkor	UG/ JICA, kade	5.60	3.26
Emo korkor	Zorko, kade	9.37	2.86
TOX 3107	UGARS, Kpong	4.31	4.30
TOX 3107	Edenic, Afife	5.42	5.93
TOX 3107	Otthofio Foods, Dawhenya	4.25	5.62
TOX 3107	IDA, Ashaiman	6.53	5.21
TOX 3108	IDA, Ashaiman	6.50	5.79
TOX 18447	Dunyo farms, Afife	4.89	4.78
Adaesi	Agro Deal, Hohoe	6.01	7.19
Perfumed	Agro Deal, Hohoe	5.78	4.66
Perfumed	Edenic, Afife	5.44	6.72
Perfumed	Otthofio Foods, Dawhenya	5.33	4.98
Perfumed	IDA, Ashaiman	5.33	7.00

Appendix 8: Regression Table for Bulk Density

Linear model: Y = a + bx   Dep. Variable: Bulk density, Indep. Variable: Moisture

Parameter	Estimate	Standard error	T-value	Prob. Value
Intercept	915.659	28.709	31.8945	0.0000
Slope	-7.16898	2.31437	-3.0976	0.00377
Coefficient of correlation = -458739 Standard error of estimation = 135223 R-squared = 21.04 percent				

Appendix 9: ANOVA table for objective colour measurement

Variable	Source of variation	Sum of squares	d.f.	Mean square	F-ratio	Sig. level
Lightness/ variety	Between groups	169.42020	8	21.177525	54.194	0.0000
	Within groups	18.75714	48			
	Total (corrected)	188.17734	56			
Redness/ Variety	Between groups	33.418225	8	4.1772781	251.00	0.0000
	Within groups	0.798842	48	0.0166425		
	Total (corrected)	34.217067	56			
Yellowness /variety	Between groups	27.304194	8	3.413024	13.187	0.0000
	Within groups	12.422831	48	.2588090		
	Total (corrected)	39.727025	56			

Appendix 10: ANOVA Table of sensory data

Appendix 10a: Colour

Variables	Source of variation	Sum of squares	d.f.	Mean square	F-ratio	Sig. level
Set 1	Main effects	162.54861	3	54.18287	48.296	0.0000
	Variety	119.17361	1	119.1736	106.226	0.0000
	Source	18.08102	2	9.04051	8.058	0.0004
	Residual	197.45139	176	1.121883		
	Total (corrected)	360.0000	179			
Set 2	Main effects	239.93519	3	79.97840	52.862	0.0000
	Variety	224.07407	1	224.07407	148.103	0.0000
	Source	15.86111	2	7.93056	5.242	0.0000
	Two-factor interactions	72.34259	2	36.171296		0.0000
	Variety/source	72.34259	2	36.171296		0.0000
	Residual	317.72222	210	15129630		
	Total (corrected)	630.00000	215			
Set 3	Between groups	162.0000	2	81.0000	634.500	0.0000
	Within groups	18.0000	141	0.12766		
Set 4	Between groups	144.83333	3	48.27778	192.196	0.0000
	Within groups	35.16667	140	0.25119		

Appendix 10b: Translucency

Variables	Source of variation	. Sum of squares	d.f.	Mean square	F-ratio	Sig. level
Set 1	Between groups	38.91204	1	38.912037	21.571	0.0000
	Within groups	321.08796	178	1.803865		
	Total (corrected)	360.0000	179			
Set 2	Main effects	201.23611	3	67.0787	33.760	.00000
	Variety	161.89352	1	161.8935	81.480	.00000
	Source	39.34259	2	19.67130	9.900	.0001
	Two-factor interactions	9.50926	2	4.754696	2.393	.0938
	Variety/source	9.50926	2	4.754696	2.393	.0938
	Residual	417.25000	210	1.986905		
	Total (corrected)	627.99537	215			
Set 3	Between groups	63.37500	2	31.687500	38.310	0.0000
	Within groups	116.62500	141	0.827128		
	Total (corrected)	179.10000	143			
Set 4	Between groups	75.22222	3	25.074074	33.503	0.0000
	Within groups	104.77778	140	0.748413		
	Total (corrected)	180.00000	143			

Appendix 11: Degree of milling (DOM) rice samples

	Variety	Source	Observation
1	Bouake 189	IDA, Ashaiman	Kernels stained mostly pink with green strips running lengthwise
2	Bouake 189	KIP, Asutsuare	Kernels stained violet with blue strips. Violet colour deep
3	Bouake 189	Goku, Akuse	Kernels stained bluish-pink (violet) with blue and green patches
4	Viwonor	Agro Deal, Hohoe	Kernels stained pinkish-blue (violet) with green strips and patches on all grains
5	WITA 9	KIP, Asutsuare	Kernels pink with green strips running lengthwise
6	WITA 9	IDA, Ashaiman	Kernels stained pink, with green and blue patches on kernels
7	Emo korkor	UG/ JICA, Kade	Kernels stained a little pinkish with blue strips
8	Emo korkor	Zorko, Kade	Pink with 2 strips of blue on each kernel. Green patch on 1 kernel
9	TOX 3107	UGARS, Kpong	Stained pink mostly, with very, very little blue spots on a few of the kernels
10	TOX 3107	Edenic, Afife	Kernels stained pink with blue strips and patches
11	TOX 3107	Otthofio Foods, Dawhenya	Kernels stained bluish-pink with a few blue strips
12	TOX 3107	IDA, Ashaiman	Pink with a few blue on kernels
14	TOX 3108	IDA, Ashaiman	Kernels stained bluish with green patches
15	TOX 18447	Dunyo farms, Afife	Kernels stained bluish-pink with blue strips
13	Adaesi	Agro Deal, Hohoe	Kernels stained pink. Very close to reference.
19	Perfumed	Agro Deal, Hohoe	Kernels stained pink with very little blue in place of germ.
16	Perfumed	Edenic, Afife	Kernels stained pink with blue strips
18	Perfumed	Otthofio Foods, Dawhenya	Kernels stained bluish-pink with blue and green patches
17	Perfumed	IDA, Ashaiman	Kernels stained bluish-pink with blue and green patches
Ranking of samples in order of decreasing pinkness (DOM) 13, 19, 9, 12, 8, 10, 1, 16, 11, 7, 18, 5, 3, 2, 15, 4, 14, 17, 6			

Appendix 12: One-way ANOVA Table for Protein

Variable	Source of variation	Sum of squares	d.f.	Mean square	F-ratio	Sig. level
Variety	Between groups	21.064066	8	2.6330083	4.451	.0013
	Within groups	17.155421	29	.5915662		
	Total (corrected)	38.219487	37			
Source	Between groups	21.064066	8	2.6330083	4.451	
	Within groups	17.155421	29	.5915662		
	Total (corrected)	38.219487	37			

Appendix 13: One-way ANOVA Table for Fat

Variable	Source of variation	Sum of squares	d.f.	Mean square	F-ratio	Sig. level
Variety	Between groups	4.4036982	8	.5504623	11.166	.0000
	Within groups	1.4296722	29	.0492990		
	Total (corrected)	5.8333704	37			
Source	Between groups	3.2126178	9	.3569575	3.314	.0030
	Within groups	2.6207526	28	.0935983		
	Total (corrected)	5.8333704	37			

Appendix 14: One-way ANOVA Table for Ash

Variable	Source of variation	Sum of squares	d.f.	Mean square	F-ratio	Sig. level
Variety	Between groups	.5067567	8	.0633446	8.931	.0000
	Within groups	.2056790	29	.0070924		
	Total (corrected)	.7124357	37			
Source	Between groups	.3770336	9	.0418926	3.497	.0052
	Within groups	.3354021	28	.0119786		
	Total (corrected)	.7124357	37			

Appendix 15: **Milled rice quality - GS 61: 1990**

Moisture – 13.5 % (m/m) fresh weight basis

Fat acidity - 20 mg

Grades and grade requirements for long (L), medium (M) and short grain rice.

Permissible Limb of fractions and other extraneous matter

Grade	Broken			Chalky			Foreign matter (%)	Red grain (%)	Insect damaged (%)	Discoloured (%)
	L	M	S	L	M	S	All sizes			
1	5	5	5	2	5	5	0.5	0	0.5	0
2	15	10	10	5	8	8	0.5	0	0.5	0
3	25	20	20	10	10	10	1	0	0.5	0
4	30	25	25	15	15	15	1	0.5	1	1
5	35	30	30	15	15	15	1	0.5	1	1

Grade	Presence of insect/ insect parts	Admixture	Definitions
	All sizes		*Long grain* – Rice with at least 75 % of whole milled kernels having a length greater than 6.6 mm
1	0	2	
2	0	2	*Medium grain* - Rice with at least 80 % of whole milled kernels having a length of between 5.0 mm and 6.6 mm
3	0	4	
4	0	20	*Short grain* - Rice with at least 80 % of whole milled kernels having a length of less than 5.0 mm
5	0	20	