

UNIVERSITY FOR DEVELOPMENT STUDIES

MOISTURE AND VARIETY EFFECTS ON THE PHYSICAL QUALITY

CHARACTERISTICS OF MILLED RICE (*Oryza sativa* L.)

ABDULAI MUJITABA

**THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL
MECHANIZATION AND IRRIGATION TECHNOLOGY, FACULTY OF
AGRICULTURE, UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER
OF PHILOSOPHY (POSTHARVEST TECHNOLOGY) DEGREE**

2016



UNIVERSITY FOR DEVELOPMENT STUDIES

**MOISTURE AND VARIETY EFFECTS ON THE PHYSICAL QUALITY
CHARACTERISTICS OF MILLED RICE (*Oryza sativa* L)**

BY

ABDULAI MUJITABA

UDS/MPHT/0004/12

**THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL
MECHANIZATION AND IRRIGATION TECHNOLOGY, FACULTY OF
AGRICULTURE, UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER
OF PHILOSOPHY (POSTHARVEST TECHNOLOGY) DEGREE**

JULY, 2016



DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:Date.....

Name:

SUPERVISORS' DECLARATION

I hereby declare that the preparation and presentation of the thesis were supervised in accordance With the guidelines on supervision of thesis laid down by the University for Development Studies.

Principal Supervisor's Signature.....Date.....

Name:

Co- Supervisor's Signature.....Date.....

Name:



ABSTRACT

Three local rice varieties, viz. Gbewaa, Nabogu and Digang were used in a research to determine the effects of moisture content at 14 %, 12 % and 10 % of paddy on milled rice quality characteristics (brown rice, white rice, head rice, broken rice, rice bran and husk yields). Three by three Factorial Design was used. Five hundred grams of each sample was milled and analysed at Ashaiman Irrigation Project's laboratory in Accra. All the three rice varieties recorded the highest head rice yield at 14 % moisture content with the average values of 55.4 %, 62.0 % and 47.1 % for Gbewaa, Nabogu and Digang respectively as against 40.64 %, 54.41 % and 38.44 % respectively at 12 % moisture content and 35.77 %, 57.60 % and 41.38 % respectively at 10 % moisture content. Conversely, all the three rice varieties recorded the highest broken grains at 10 % moisture content with the average values of 31.93 %, 16.81 % and 32.33 % for Gbewaa, Nabogu and Digang respectively. The highest rice bran and rice husk yields were recorded at 10 % moisture content; with the exception of Gbewaa rice which recorded the highest average husk yield of 24.19 % at 10 % moisture content. Milling at 14 % moisture content is thus recommended for better physical quality characteristics of Gbewaa, Nabogu and Digang rice varieties.



ACKNOWLEDGEMENTS

I am very grateful to the Almighty God for His mercy and guidance which were showered on me during my research work.

The unflinching support, guidance and directions of my supervisors, Chief Awudu Abukari and Dr. Martin A. Ofosu cannot be overemphasized; may God shower His compassion and success on them in all their endeavours.

I am indebted to the Head of the Department of Agricultural Mechanisation and Irrigation Technology and other lecturers of the department. I also acknowledge the support of Dr. Francis Kweku Amagloh, not excluding my colleague, Mr. Paul Azure and all workers of Ashaiman Irrigation Technology, I say thank you.



DEDICATION

This work is dedicated to my dear mother, Hajia Samata Salifu Limambia.



TABLE OF CONTENTS

CONTENTS	PAGE
DECLARATION	i
ABSTRACT.....	ii
ACKNOWLEDGEMENTS	iii
DEDICATION	iv
TABLE OF CONTENTS.....	v
LIST OF TABLES	x
LIST OF FIGURES	xii
LIST OF PLATES	xiii
ACRONYMS AND ABBREVIATIONS	xv
CHAPTER ONE	1
1.0 INTRODUCTION	1
1.1 Background.....	1
1.2 Problem Statement and Justification	3
CHAPTER TWO	6
2.0 LITERATURE REVIEW	6
2.1 Rice Taxonomy and Botany	6
2.2. Origin and Distribution of Rice	7
2.3 Rice Production and consumption around the World.....	8
2.4 Rice production and consumption in Africa.....	8
2.5 Rice Production and Consumption in Ghana	9
2.6 Agronomic and Morphological Characteristics of local rice varieties	14
2.6.1 Digang	14
2.6.2 Gbewaa	14
2.6.3 Nabogu.....	15
2.7 Attempts to Improve Upon the Rice Industry in Ghana.....	17





2.8 Importance of Rice	19
2.8.1 Food Security.....	19
2.8.2 Employment and Income Source.....	21
2.8.3 Socio – Cultural Uses	21
2.8.4. By-products of Rice.....	22
2.9 Rice Milling in Ghana	22
2.10 Rice milling processes.....	24
2.10.1Pre Cleaning	24
2.10.2De-stoning	26
2.10.3 Parboiling.....	26
2.10.4 Husk Aspiration.....	27
2.10.5 Paddy Separation	29
2.10.6 Whitening or polishing process	30
2.10.7 Length Grading.....	31
2.10.8 Blending.....	31
2.10.9 Weighing and bagging.....	31
2.11 Importance of Measuring Moisture Content of Paddy.	32
2.12 Broken rice grain	34
2.13 Head Rice	35
2.14 Milling degree.....	35
CHAPTER THREE	36
3.0 MATERIALS AND METHODS	36
3.1 Experimental Site	36
3.3 Sampling and Sample preparation.....	38



3.4 Determination of some physical quality characteristics of milled rice	38
3.4.1 Brown rice	38
3.4.2 Husk	39
3.4.3 Bran	39
3.4.4 Head grain	39
3.4.5 Broken grain	39
3.5 Data processing	39
CHAPTER FOUR	40
4.0 RESULTS	40
4.1 Percentage presentation of the physical quality characteristics of different rice varieties milled at different moisture contents	40
4.1.1 Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 14 % moisture content	40
4.1.2 Percentage presentation of the physical quality characteristics of Nabogu rice milled at 14 % moisture content	40
4.1.3 Percentage presentation of the physical quality characteristics of Digang rice milled at 14 % moisture content	41
4.1.4 Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 12 % moisture content	42
4.1.5 Percentage presentation of the physical quality characteristics of Nabogu rice milled at 12 % moisture content	42
4.1.6 Percentage presentation of the physical quality characteristics of Digang rice milled at 12 % moisture content	43



4.1.7 Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 10 % moisture content	44
4.1.8 Percentage presentation of the physical quality characteristics of Nabogu rice milled at 10 % moisture content	44
4.1.9 Percentage presentation of the physical quality characteristics of Digang rice milled at 12 % moisture content	45
4.1.10 Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 14 % moisture content.....	46
4.1.11 Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 12 % moisture content.....	46
4.1.12 Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 10 % moisture content.....	47
4.2 Brown rice yield as influenced by moisture content and variety	48
4.3 White rice yield as influenced by moisture content and variety.....	48
Figure2: White rice yield as influenced by moisture content and variety	49
4.4 Broken grain yield as influenced by moisture content and variety	49
4.5 Head rice yield as influenced by moisture content and variety	50
4.6 Rice bran yield as influenced by moisture content and variety	51
4.7 Rice husk yield as influenced by moisture content and variety	54
CHAPTER FIVE	55
5.0 DISCUSSION	55
5.1 Moisture and variety effects on brown rice yield	55
5.2 Moisture and variety effects on white rice yield	55
5.3 Moisture and variety effects on broken grain yield	56

5.4 Moisture and variety effects on head rice yield.....	58
5.5 Moisture and variety effects on rice bran yield	59
5.6 Moisture and variety effects on rice husk yield.....	59
CHAPTER SIX	61
6.0 CONCLUSIONS AND RECOMMENDATIONS	61
6.1 Conclusions	61
6.2 Recommendations	61
REFERENCES	62



LIST OF TABLES

Table	Page
Table 1: Categorisation of paddy fields in Ghana	11
Table 2 : Agronomic and morphological characteristics of local rice varieties	15
Table 3: Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 14 % moisture content	40
Table 4 : Percentage presentation of the physical quality characteristics of Nabogu rice milled at 14 % moisture content	41
Table 5: Percentage presentation of the physical quality characteristics of Digang rice milled at 14 % moisture content	41
Table 6: Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 12 % moisture content	42
Table 7: Percentage presentation of the physical quality characteristics of Nabogu rice milled at 12 % moisture content	43
Table 8: Percentage presentation of the physical quality characteristics of Digang rice milled at 12 % moisture content	43
Table 9: Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 10 % moisture content	44
Table 10: Percentage presentation of the physical quality characteristics of Nabogu rice milled at 10 % moisture content	45
Table 11: Percentage presentation of the physical quality characteristics of Digang rice milled at 10 % moisture content	45



Table 12: Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 14 % moisture content	46
Table 13: Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 12 % moisture content	47
Table 14: Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 10 % moisture content	47



LIST OF FIGURES

Figure	Page
Figure 1: Brown rice yield asinfluenced by moisture content and variety	488
Figure 2: White rice yield as influenced by moisture content and variety	499
Figure 3: Broken rice yield as influeced by moisture content and variety	50
Figure 4: Head rice yield as influenced by moisture content and variety.....	511
Figure 5: Rice bran yield as influenced by moisture content and variety.....	522
Figure 6: Rice husk yield as influenced by moisture content and variety	533



LIST OF PLATES

Plate	Page
Plate 1: Rice varieties used	744
Plate 2: paddy samples in drying trays	744
Plate 3: Experimental machine used to mill the rice samples.....	755
Plate 4: Grading machine.....	755
Plate 5: Rice polishing machine.....	76
Plate 6: Moisture meter	76



LIST OF APPENDICES

Appendix	Page
A 1. Analysis of variance for rice brown yield (g)	711
A 2. Analysis of variance for white rice yield (g).....	711
A 3. Analysis of variance for head rice yield (g).....	722
A 4. Analysis of variance for broken grain yield (g)	722
A 5. Analysis of variance for rice husk yield (g).....	733
A 6. Analysis of variance for rice bran yield (g)	733



ACRONYMS AND ABBREVIATIONS

AGRA	Alliance for Green Revolution in Africa
CARD	Coalition for African Rice Development
CRI	Crop Research Institute
CSIR	Council for Scientific and Industrial Research
DOM	Degree of Milling
FAO	Food and Agriculture Organisation
FASDEP	Food and Agricultural Sector Development Policy
FSEP	Food Security and Emergency Preparedness Programme
GFSR	Global Food Security Response
GSSP	Ghana Strategy Support Programme
HRV	Head Rice Yield
IFPRI	International Food Policy Research Programme
IRRI	International Rice Research Institute
JICA	Japan International Corporations Agency
LRAN	Land Research Action Network
MAFAP	Monitoring African Food and Agricultural Policies
MC	Moisture Content
METASIP	Medium Term Agriculture Sector Investment Plan
MOFA	Ministry of Food and Agriculture
MT	Metric ton
NRDS	National Rice Development Strategy



ODI	Overseas Development Institute
PRSPs	Poverty Reduction Strategy Papers
SARI	Savanna Agriculture Research Institute
SRID	Statistics, Research and Information Directorate
UNCTAD	United Nations Conference on Trade and Development
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WARDA	West African Rice Development Agency
WFP	World Food Programme



CHAPTER ONE

1.0

INTRODUCTION

1.1 Background

Rice (*Oryza spp*) is the most widely cultivated cereal in the world, after wheat, and it is the most important food crop for almost half of the world's population (IRRI, 2010). It is estimated that rice sustains the livelihood of hundred million people and its production has employed more than twenty million farmers in Africa (WARDA, 2005). Rice has high calorie and nutritional value, easily digestible starch and carbohydrates, and if whole, contains high amount of potassium, phosphorus, magnesium and iron (Balasubramaniyan, 2001). FAO (2004) declared the year 2004 as the international year of rice, because of its contribution to food security and to income generation and political stability.

Statistics show that in the world markets, the fissured rice kernels in the offered product decrease its economical value, since broken kernels are typically worth half the value of full kernels (Siebenmorgen and Qin, 2005). Rice fissuring depends on many factors including farm management, moisture level at harvesting, processing time, drying method and devices that are used for its milling. Moreover, the quality of rice, especially, breakage is influenced by cultivars, conditions of climate, post-harvest operations, milling degree and cooking process (Champagne *et al.*, 1990; Champagne *et al.*, 1997). Two important factors in rice milling quality are head rice yield (HRY) and degree of milling (DOM). HRY is the weight percentage of rough rice that remains as sound kernels (equal or greater than $\frac{3}{4}$ intact kernels) after milling. DOM is defined as the extent to which the germ and bran layers of brown rice kernels are removed during the milling process (USDA, 1990).



The rice grain is covered by a hull and bran which are indigestible by humans. The rice endosperm, obtained after removing the outer layers of hull and bran of the paddy and the germ, is mainly starch and is consumed as cooked intact grains along with vegetable pulses, meat or fish (Sivasankar, 2010).

Focusing on the period 2005-2010, rice production accounted for about 19 percent of cereal production in Ghana (MoFA, 2010). Rice production takes place in all the ten regions of Ghana; which also cover all the major ecological/climatic areas including the interior savannah area, the high rain forest zone, the semi-deciduous rain forest area and the coastal savannah area with peak production occurring in the Northern, Upper East, Western, Brong Ahafo and Volta Regions (ODI, 2003).

Rice is obtained by milling the paddy. The paddy is fed to machines called shellers or hullers consisting of discs (rubber or metal). The grains are not crushed but the hull is rubbed off from the underlying kernels. The hulls are separated from the kernels by jets of air leaving the brown rice. The brown rice is polished using a brush machine to remove the aleurone layer. The milled rice contains mainly unbroken kernels and some amount of broken kernels which are separated by screening (Sivasankar, 2010).

Paddy is often milled at 14 % moisture content, but depending on moisture content and type of variety, rice breakage may be affected (IRRI, 2010). Paddy rice is parboiled before milling to reduce grain losses during milling. Parboiling involves soaking paddy in water for a short time, followed by heating in steam and drying before milling. Parboiled rice is relatively more nutritive compared to non-parboiled rice as vitamins and minerals are solubilised from the hull



and bran and deposited on the endosperm during soaking and steaming. In addition, parboiled rice is more resistant to fungus and insect attack (Sivasankar, 2010).

Parboiling of rice helps in improving the nutritional quality by gelatinization of starch inside the rice grain. It also improves milling recovery percentage during de-shelling and polishing (IRRI, 2010). Grain quality of rice is an important criterion that is taken into consideration by farmers and consumers. Farmers select rice with traits that are desired by consumers (Horna *et al.*, 2005). Apori-Buabeng (2009) reported that consumers in Ghana prefer stone free rice and rice with low percentage of broken grains.

Traore (2005) reported that more importance would be attached to rice grain quality in the near future because consumers would always demand high quality rice. The quality is usually defined by the consumer, and this varies from one place to another. Consumers in the Middle East, for instance, have more taste for long grain rice that is well milled and has aroma. On the other hand, consumers in Europe have taste for long grain rice that has no aroma. Takoradi (2008) revealed that in West Africa and for that matter Ghana, quality is dependent on the type of food with which rice would be used to prepare. But generally, consumers give more value to head rice grains (rice with lesser breakage).

1.2 Problem Statement and Justification

Abundant world rice supply has led to renewed interest in improving grain quality of modern rice varieties. High quality rice attracts high prices which are used to evaluate rice breeding goals and estimate returns to research for quality improvement (Unnvehr, 1986). Poor perception of consumers concerning local rice has also adversely affected its production and consumption. It is a general knowledge that there is a preference for imported rice and that local



rice has no competitive advantage against imported rice (Apori-Buabeng, 2009). Four (4) out of the eleven (11) largest rice importing countries in the world are within sub-Saharan Africa with Nigeria as the world's largest importer (WARDA, 2005). Ghana has been importing significantly large quantities of rice to address quality and quantity differences between local productions and demands (Amanor-Boadu, 2012).

Improvement on local rice quality is a strategy to reduce dependency on importation. Local rice has not been economically competitive and there is insufficient information on it. The use of appropriate post-harvest technology procedures could help improve rice quality (Guisse, 2010). One of the major problems of rice industry is breakage of kernels during milling. As cooking quality of broken rice is very poor, the market value with broken grain is much less than that for whole grains (Li *et al.*, 1999). The ultimate goal of the rice industry is to achieve maximum head rice yield (HRY) from the milling process. HRY is the current standard to assess commercial rice milling quality (Iguaz *et al.*, 2006). The breakage of rice in milling process is influenced by several factors. Besides rice variety, paddy moisture content also affects the extent of kernel damage. Kernel breakage is closely related to fissure development in different stages of harvesting and post harvesting operations. Among factors affecting the broken kernels during milling process, final moisture content of paddy is one of the important influencing parameters on quantitative and qualitative milling (Peuty *et al.*, 1994).

Paddy moisture content and the type of variety greatly affect rice grain breakage. The different rice varieties give out different yield components during milling (IRRI, 2010). In most markets, broken kernels are valued at only 50 to 60 percent that of head rice, thus underpinning the tremendous impact that HRY has on the economic value of a rice lot, and also justifying the need



for laboratory milling systems to accurately determine this important parameter .The ideal moisture content for milling is between 12 to14 %, depending on the type of variety (IRRI, 2010). Most millers in Ghana do not have the moisture meters to accurately determine paddy moisture content during the milling process (Guisse, 2010). The three varieties (Gbewaa, Nabogu and Digang) being looked at are relatively new in the Ghanaian system with high preference from the populace. Investigating the ideal moisture content that will improve upon their physical quality characteristics is important. Thus, the objective of the study was to determine the interactive effects of moisture content and variety on the physical quality characteristics of milled Gbewaa, Nabogu and Digang paddy.



CHAPTER TWO

2.0

LITERATURE REVIEW

2.1 Rice Taxonomy and Botany

Rice (*Oryza spp*) belongs to the Family Graminae. It is described as a cereal grain grown in hot countries providing seeds that are used as food. Rice refers to two grass species (*Oryza sativa* and *Oryza glaberima*) and it is native to tropical and subtropical south eastern Asia and to Africa. The plant has long, flat, pointy leaves and stalk-bearing flowers which produce the grain known as rice. It can grow up to 1-1.8m tall or more depending on the variety and the soil fertility. As a member of the grass family, rice has long, slender leaves between 50-100 cm long and 2-2.5cm broad (Boumas, 1985).

Rice is related to other grass plants such as wheat, oats and barley which produce grain for food and are known as cereals. Rice is in genetic diversity with thousands of varieties grown throughout the world (IRRI, 2010). The domesticated rice comprises two species of food crop in the poaceae (“true grass”) family: *Oryza sativa* and *Oryza glaberima* (Linsconbe, 2006). It is an important crop in subtropical and temperate zones, the yield being higher in temperate areas than in the tropics.

Rice grain is rough rice or paddy, consisting of kernel and the hull. Brown rice consists of the endosperm, embryo and several thin layers of differentiated tissues-the pericarp (the ovary wall), the seed coat and the nuclelus (Li, 2003). The seed coat consists of six layers of cells, with the aleurone layer, being the innermost. The embryo contains the embryonic leaves (plumule), enclosed by a sheath (coleoptiles), embryonic primary root (radical) unsheathed by the coleorhizae, and the joining part (mesocotyl). Rice endosperm consists mostly of starch granules



in a proteinaceous matrix, together with sugar, fats, crude fibre, and organic matter. Hull weight is about 20 % of the total grain weight. The hull of some rice grains has the palea, lemmas and richilla, while others have rudimentary glumes and perhaps a portion of the pedicel (Li, 2003). Knowledge about grain quality starts with knowing the anatomy of a single grain, whether the grain is to be used for feed or for human consumption.

2.2. Origin and Distribution of Rice

Approximately 4000 years after the domestication of cereals began, the cultivation of rice occurred south of the Yangtze River (Vaughan *et al.*, 2008). It is believed that rice cultivation began simultaneously in many countries over 6500 years ago. The first crops were observed in China (Hemu Du region) around 500 B.C. as well as in Thailand around 4500 B.C. They later appeared in Cambodia, Vietnam and Southern India. From there, derived species, Japonica and Indica expanded to other Asian countries such as Korea, Japan Myanmar, Pakistan, Sri Lanka, Philippines and Indonesia. The Asian rice (*Oryza sativa*) was adapted to farming in the Middle East and Mediterranean Europe around 800 B. C. The Moros brought it to Spain when they conquered the country, near 700 A. D. After the middle of the 15th century, rice spread throughout Italy and then France, later propagating to all the continents during the great age of the European exploration. In 1694, rice arrived in the South Carolina, probably originating from Madagascar. The Spanish took it to South America at the beginning of the 18th century (UNCTAD, 2010).

The first cultivators of rice did so by accident after a storm damaged ship docked in the Charleston South Carolina Harbor. The captain of the ship handed over a small bag of rice to a



local planter as a gift, and by 1726, Charleston was exporting more than 4,000 tonnes of rice per year (Proctor, 2010).

In the United States, farmers have been successfully harvesting rice for more than 300 years. There are thousands of strains of rice today, including those grown in the wild and those which are cultivated as crops (USDA, 2008).

The African species of rice (*Oryza glaberina*) was cultivated long before Europeans arrived on the continent. At present, *Oryza glaberrimas* are being replaced by the introduced Asian species of rice, *Oryza sativa*. Some West African farmers, including the “Jollas” of southern Senegal, still grow African rice for use in ritual contexts (Linares, 2002). Rice is cultivated on all the continents except Antarctica (Li, 2003).

2.3 Rice Production and consumption around the World

More than 550 million tonnes of rice is produced annually around the globe. The majority of all rice produced comes from India, China, Japan, Indonesia, Thailand, Burma and Bangladesh. Asian farmers account for 92 % of the world’s total rice production. (Rose *et al.*, 2009). Around the world, rice cultivation has been a principal activity and a source of income for millions of households, and several countries of Asia and African are highly dependent on rice as a source of foreign exchange earnings and government revenue (IRRI, 2010). Today, it is the second most important cereal in the world. Rice, together with wheat provides a larger proportion (95 %) of the total nourishment of the world’s population (Juliano, 1993).

2.4 Rice production and consumption in Africa

There is a growing rice consumption trend in sub-Saharan Africa which can be attributed to factors such as population growth and urbanization, consumer preference and diet changes, the



convenience of cooking and the ease of storage of rice. Rice is the most rapidly growing food source in sub Saharan African with consumption growing at 5 % per annum, since 1961 (Nwanze *et al.*, 2006).

The increasing importation of rice in the sub Saharan African region has its consequence on the region as it is causing rice production in the region not to keep pace with its consumption. The region accounts for more than 30 % of world rice imports with an import bill of about US \$2 billion per year. The African Rice centre has projected that by 2015, total Africa rice imports could reach up to 20 million tonnes of milled rice per year and that most of the imported rice will go to the Western coast of Africa like Nigeria, Senegal, Cote d'Ivoire, Cameroon, Ghana and Benin (WARDA, 2008). The main rice producing regions in Ghana, Northern, Volta and Upper East regions, produce between 45000-60 000 tonnes per year each. The Northern region is the main producer with about 63000 tonnes in 2009 (USAID, 2009). Most of the rice is cultivated from low-quality seed with mixed varieties, which brings about uneven maturity at harvest and wide variations in the size and shape of rice grains. Generally, this results in a gap between the quality of local and imported rice.

2.5 Rice Production and Consumption in Ghana

Rice production is undertaken in three different ecologies: lowland rain-fed ecology, which includes rice planted in the receding waters of the Volta and other rivers (78 percent of production); upland rain-fed ecology (6 percent), and irrigated ecology (16 percent), (CARD, 2010). Lowland production is mainly practiced by women in lowland areas, and is often done without supplementary irrigation. Rain-fed rice production contributes 84 percent of total current production, generating average paddy yields of 1.0-2.4 metric tonnes per hectare, while irrigated



production accounts for just about 16 percent of production but produces the highest average paddy yields of 4.5 metric tonnes per hectare (CARD, 2010). Rain fed lands and swampy areas producers are able to plant rice in two seasons as the rainfall pattern in these areas is bimodal in nature from between March to July and September to November.

There are currently 22 public irrigation schemes in Ghana. The larger schemes include the Kpong Irrigation Scheme, the Tono Irrigation Scheme, the Veia and Afife Irrigation Schemes (CARD, 2010). While most of the irrigation schemes are used for rice cultivation, the four largest schemes listed above are used for rice and vegetable cultivation. Furthermore, in addition to the 19000 hectares of irrigated farmland in Ghana, 10,900 are under government-run irrigation, the rest are privately-run.

Ghana's rice production estimates range from 200,000 to 300,000 metric tonnes of paddy or roughly 120,000 to 180,000 metric tonnes of milled rice, the bulk of which comes from the Upper East, Northern and Volta Regions. Rainfall remains the greatest driver of production variance. Rice production expanded steadily from 1994 to 2004 primarily from an expansion of land under paddy production (GFSR, 2009).



Table 1: Categorisation of paddy fields in Ghana

	Lowland rain-fed	Upland rain-fed	Irrigated	Total
Planted Area (Ha)	93,750	18,750	10,200	122,700
Paddy (MT/Ha)	2.4	1.0	4.5	2.4
Paddy Production (MT)	224,700	18,750	45,900	289,350
% of Total Area	76	15	8	100
% of Total Production	78	6	16	100

Source: *MoFA and JICA* (2008).

By the end of 2008, rice production in Ghana was estimated at 301,921 metric tonnes of paddy, yielding roughly 181,000 metric tonnes of milled rice, produced on 132,921 hectares, resulting in an average yield of 2.27 mt/ha of paddy for upland and lowland rice aggregated. It is generally agreed that current domestic production accounts for between 30 to 40 percent of domestic consumption (approximately 600,000 metric tonnes of milled rice). Current rice yields vary considerably by cropping type but average yields are 2.5 to 4.2 mt/ha in the major season and 2.1 to 3.5 mt/ha during the minor season. This compares to 9.8 mt/ha for Egypt, 7 mt/ha for the U.S. and Japan, and 4 mt/ha for Vietnam. At the same time, Ghanaian yields are relatively high given the lack of access to improved seed, agro-chemicals and appropriate mechanization. It can be assumed that, given access to these resources, Ghana could produce rice at reasonably high levels of efficiency (GFSR, 2009).





Ghana's potential for irrigated perimeters is 1.9 million hectares, roughly 0.46 percent of which is currently developed. Since the 1960s, 22 public irrigation schemes totaling 8,700 hectares have been established and are currently used for the production of rice, maize and vegetables. The ongoing Millennium Challenge Account-funded program seeks to bring an additional 5,200 hectares under cultivation, with 1,400 hectares in the north, 800 hectares in the Afram Basin and 3,000 hectares in the southern agricultural zone. Mechanization levels in rice production are low throughout Ghana, although most farmers hire tractor services for plowing and harrowing. In the Northern Regions, bullock-drawn ploughs are also common. All other production and post-harvest activities are done manually, especially by smallholders. Other constraints to production include low land-leveling of paddy fields and lack of bunds to retain rain water; inadequate supply of certified seed, fertilizers and other agro-chemicals; and inadequate credit facilities to ensure investment in productivity-enhancing technologies (GFSR, 2009).

According to Chipili *et al.* (2003) rice is the number one staple food in Ghana. There has been a rapid dietary shift to rice in Ghana, particularly in the urban centres, starting from early post-independence period. The trend was attributed to increased income, favourable government pricing policies of rice and ease of coking (Nyanteng, 1987). Per capita rice consumption increased from 17.5kg to 38kg between the years 1999 and 2008, and it is estimated to get to 63kg by the year 2018 (MOFA, 2009a).

From independence in the 1950s through 1982, the government intervened heavily in the rice sector. Stiff restrictions were imposed on imports to encourage domestic production, partially in response to an overvalued currency that made imports more affordable. Between 1983-1986 and 1987-1991, two phases of stabilization policies following economic crises were implemented.

Despite a drastic decrease in protection of the food sector and subsidies for inputs, devaluations and trade and marketing reforms favored local production over imports. Imported rice was about 10 percent cheaper than domestic rice before the adjustment programs started in 1983, and over 25 percent more expensive at the wholesale level after 1984. In 2003, Ghana's parliament passed a budget that raised rice tariffs by 5 percent, but the increase was not implemented by customs and was then repealed in 2005 (GFSR, 2009).

Rice is important to Ghana's economy and agriculture, accounting for nearly 15 % of the Gross Domestic Product. This sector agriculture provides employment for a lot of rural dwellers. Due to the shift in the diet, of Ghanaians to rice consumption, particularly those in the urban areas, imports of rice have been increasing steadily since the 1980s. Imported rice is estimated to account for more than 50 % of all rice consumed in the country (Berisavljevic *et al.*, 2003).

In 2010, rice was the 10th agricultural commodity in Ghana by value of production while it ranked 8th in terms of production quantity for the period 2005-2010 (MoFA, 2010). It occupies roughly 4 percent of the total crop harvested area, although it accounts for about 45 percent of the total area planted to cereals (MoFA, 2009c). In addition to being a staple food mainly for high income urban populations, rice is also an important cash crop in the communities in which it is produced. Between 2005 and 2007, Ghana ranked among the top 50 rice producers worldwide, dropping out of the list only in 2010 (FAOSTAT, 2012).

The dependency on rice imports is common to many West African countries. Following the 2008 world food crises however, the annual rate of increase of West Africa's rice production went up from 3.8 percent to 5.4 percent. Rice consumption has however stabilized at between 5-6 percent. However, similarly to a number of West African countries such as Benin, Guinea,



Liberia and Nigeria, Ghana witnessed an increase in demand for substitutes such as cassava with evidence being offered in the increase in the production and trade of cassava flour since 2008 (WFP, 2010).

Ghana's current rice consumption estimates range around 30 kg/capita per year with projected demand in 2015 of as much as 63 kg/capita per year driven by steady gains in income and a population growth of 27.5 percent. Consistent with income patterns and Ghana's diverse range of carbohydrate sources, rice consumption in rural areas (where poverty levels are higher) is much lower than in urban areas. Rice comprises only about 10 percent of total carbohydrate consumption, and rural consumers, especially those producing alternative cereal and tuber crops are less vulnerable to rice price fluctuation than urban ones. By contrast, in urban areas, there is a strong preference for long grain aromatic rice, which is principally imported from Vietnam or Thailand and for which there are few locally available substitutes (GFSR, 2009).

2.6 Agronomic and Morphological Characteristics of local rice varieties

2.6.1 Digang

The plant of digang rice has an average height of 114cm. Its husk colour is brown. It has good tiller ability and its basal leaf sheath colour is green. It is hydromorphic and a lowland rice with potential yield of 5000kg/ha. Its maturity ranges between 110 and 115 days after planting.

Digang has good resistance to diseases, insects and lodging (CSIR-SARI, 2010).

2.6.2 Gbewaa

Gbewaa rice plant has an average height of 91cm. Its husk colour is yellow. It has very good tiller ability and its basal leaf sheath colour is green. It is irrigated and rain fed lowland rice with



potential yield of 6900kg/ha. Its maturity ranges between 110 and 115 days after planting. It also has good resistance to diseases, insects and lodging (CSIR-SARI, 2010).

2.6.3 Nabogu

The plant of Nabogu rice has an average height of 136cm and its leaf angle is erected. Its husk colour is yellow. It has very good tiller ability and its basal leaf sheaf colour is purple. It is irrigated and rain fed lowland rice with potential yield of 6500kg/ha. Its maturity ranges between 122 and 126 days after planting. It also has good resistance to diseases, insects and lodging (CSIR-SARI, 2010).

Table 2: Agronomic and morphological characteristics of local rice varieties

Variety	Maturity period(days)	Yield (kg/ha)	Ecology	Plant average height (cm)	Husk colour
Digang	110-115	5,000	Hydromorphic and lowland	114	brown
Gbewaa	110-115	6,900	Irrigated and rain fed lowland	91	yellow
Nabogu	122-126	6,500	Irrigated and rain fed lowland	136	Light yellow

Source: CSIR-SARI (2010)

Digang rice variety was officially released in 2002. It is early maturing and is good for drought-prone areas, and can be grown in different rice ecologies. In 2009 and 2010, seven lowland varieties were released (in addition to the four varieties for upland rice ecologies already described above), two of which are aromatic (Jasmine 85 and Marshall). Jasmine 85 was officially released in 2009, although many farmers were already planting it prior to 2009. Jasmine 85 is an advanced variety, with germplasm originating from IRRI and further developed and registered by the University of Texas A&M. It is likely that the Jasmine 85 that has spread in



Ghana is the version from Texas A&M, although no one seems to know how it got to CSIR or MOFA. The four varieties released in 2010 are described as blast tolerant, high yielding, and with good milling properties. Marshall or Amankwatia is seen to have a great potential, as it is both high yielding and aromatic.

What is interesting about the rice seed sector are the numerous varieties of rice grown by farmers in Ghana outside the officially released ones. The 2007 CRI annual report included a list of 70 names of local and modern varieties (although several may be the same varieties but are called by different names in different locations). The report identified 29 upland varieties and 41 lowland varieties that were planted by farmers (CRI 2010). However, there is no systematic and regular cataloging of varieties and testing, and the lack of funding is often cited as the reason. Varieties that are believed to be modern or improved are also being evaluated by CSIR; these are promoted by projects and with small production of certified seed supported by MOFA. These varieties include WITA 7, Togo Marshall, Jet 3, and Aromatic short, although little is known about them within CSIR. WITA 7 is believed to be widely grown in West Africa; it was recommended by CRI earlier but not officially released (personal communication with Dr. Kofi Dartey of CRI). A production guide promoting WITA 7 describes it as a medium-maturing variety with a 4.5–6.0 tons/hectare average yield. Togo Marshall is aromatic and reported to be preferred by importers and millers in Ashanti region and by traders in Volta region (based on key informants' interviews). Tests have only recently been conducted to determine whether Togo Marshall is the same as Marshall or Amankwatia, which is one of the released varieties. CSIR (personal communication with CSIR researchers) suggests that Amankwatia and Togo Marshall are different, although further tests are needed to ascertain this. Aromatic short, as the name



implies, is aromatic and a shorter plant than Jasmine 85. It is believed to have been introduced by a private company and was initially called Jasmine 85; further testing by CSIR indicates that it is a different variety, since it is a shorter plant than Jasmine 85, although other traits are very similar to Jasmine 85 (GSSP, 2013).

Official records of certified seed production reveal that certified seed production in the last 12 years has been dominated by three varieties: Jasmine 85, GR 18, and TOX 3107 (accounting for 91 percent of certified seed production). Half of certified seed production from 2001–2011 was Jasmine 85, 27 percent was GR 18, and 15 percent was TOX 3107. Faro 15, Sikamo, Digang, WITA 7, and Bodia accounted for 1–5 percent (80–500 tons). A few other varieties had certified seed production of 1–40 tons total for 11 years, namely Aromatic short, Jet 3, Togo Marshall, NERICA 1, NERICA 2, and IR 64. Only a few varieties have certified seed production in the most recent years (2010–2011): Jasmine 85, GR 18, TOX 3107, Aromatic short, Jet 3, and Togo Marshall (GSSP, 2013).

2.7 Attempts to Improve Upon the Rice Industry in Ghana

Since the 1970's efforts have been made by various governments to develop the rice industry. Such efforts have proved unsuccessful due to a lot of limiting factors, among them include, lack of research and extension support, inappropriate production system, inadequate basic infrastructure and inappropriate marketing strategy. Between 1989 and 1996, there was a steady increase in rice production at the rate of 13 % per annum due to area expansion. Yield increased from 0.9kg/ha to 2.4kg/ha (MOFA, 2009a).

Agricultural policies to develop the rice industry in Ghana date back to the 1970's. However, the removal of input subsidies as part of the Structural Adjustments Programmes in the 1980's



brought about a decline in local rice production. Since then, several programmes have been developed to boost the industry. The first Food and Agricultural Sector Development Policy (FASDEP I), formulated in 2002, was designed to provide a policy framework for modernizing agriculture and promoting rural growth. FASDEP I especially sought to decrease rice imports by 30 percent by 2004 by boosting domestic production levels to 370,000 tonnes. This target was however not reached. The second Food and Agricultural Sector Development Policy (FASDEP II) was then developed in 2007 but implemented in 2009 (CARD, 2010). FASDEP II intends to achieve food security via the promotion of five staple food crops (cassava, cowpea, maize, rice and yam). Pertaining to rice production, FASDEP II pays particular attention to developments along the rice value chain. In contrast to FASDEP I however, FASDEP II seeks to control agricultural imports by applying standards instead of quotas and import tariffs (CARD, 2010).

As part of FASDEP II, the Ghana's Medium Term Agriculture Sector Investment Plan (METASIP) 2009/2015, and the Food Security and Emergency Preparedness Programme (FSEPP), have been initiated to increase agricultural productivity (including increasing rice yields) by 50 percent. The productivity of irrigation schemes as well as the intensification of irrigation is to be increased by 25 percent and 50 percent respectively by the end of 2012 (MOFA, 2007). In support of FASDEP II, over 20 rice-related projects have been implemented or are in process of being implemented.

As part of an initiative to boost the development of the rice subsector, the Ministry of Food and MoFA together with the Alliance for Green Revolution in Africa (AGRA), CARD, and JICA have developed a rice sub-sector strategic plan in collaboration with stakeholders in 2008. This National Rice Development Strategy focuses on seven thematic areas, namely, Seed production



system, Fertilizer marketing and distribution, Post-harvest handling and marketing, Irrigation and water control investment, Equipment access and maintenance, Research and technology dissemination, as well as Community mobilization, farmer-based organizations and microcredit management.

2.8 Importance of Rice

2.8.1 Food Security

Rice is an essential food in the diet of one third of the world's population (Juliano, 1993). It is a major staple food for millions of people in West Africa. The annual demand for rice in the sub-Region is estimated at over 8 million metric tones (Basorun, 2003). Rice is becoming an increasingly important staple food consumed through out Ghana. It has been estimated that between 1980 and 2005, the per capita consumption of Ghana increased from 12.4 to 15.1kg/year (MOFA, 2009c).

Rice is one of the cheapest sources of food energy and protein content. It is from the cereal group which constitutes the bulk of the food consumed by humans. The rice grain contains almost 80 % protein, and less than 1 % of minerals, particularly phosphorus. Starch is the major constituent of carbohydrates with smaller amounts of free sugars such as glucose, sucrose and dextrin (Sivasankar, 2010).

Rice is naturally free of fat, cholesterol and sodium. It is a complex carbohydrate containing only 103 calories per one-half-cup serving. It provides more than 50 percent of the daily calories ingested by more than half of the world's population (UNCTAD, 2010).

Rice meals are the second dominant meals consumed after maize in Ghana. For the fact that in all hotels, restaurants, 'chop bars', food vendors, etc, rice meals are more frequent than other



meals. Rice meals are the preferred meals that are served during occasions such as festivals, funerals, weddings and out-doorings (Ayamdoo, 2013).

Rice is also the first imported cereal in the country accounting for 58 percent of cereal imports (CARD, 2010), accounting for 5 percent of total agricultural imports in Ghana over the period 2005-2009. In Ghana, rice is considered to be among the main staples with rice consumption in 2011/12 estimated to reach 62,000 mt (CARD, 2010). Per capita consumption of rice in 2010 and 2012 is pegged at about 28 kg with urban areas accounting for about 76 percent of total rice consumption (CARD, 2010). In urban areas, rice is preferred over other staples as it is easy and convenient to prepare and it allows for a wide variety of dishes. In addition, the rising number of fast food restaurants and vendors in the major cities has increased the demand for rice. Rice consumption in rural areas is much lower than in urban areas and thus less vulnerable to price fluctuations. Although rice displays a high income elasticity of demand, over the last ten years, per capita rice consumption has raised by over 35 percent due to changes in food consumption patterns driven by urbanization (FAO, 2004). Rice consumption is highest around the festive seasons of Christmas and Easter. High quality white rice is consumed on a regular basis in urban areas where the concentration of people with a stable income is higher. According to the Ministry of Food and Agriculture just about 20 percent of locally cultivated rice is consumed in urban areas due to consumer preferences for long grain aromatic rice which is principally imported from Vietnam and Thailand.

At present there are no local types of rice which can be considered as substitutes of the imported rice. Without an increase in quality, the urban population who typically consumes more rice than rural consumers due to the convenience will continue to buy imported rice. Rice is the most



important grain with regard to human nutrition and caloric intake, providing more than one fifth of the calories consumed worldwide by the human species. Rice constitutes the world's principal source of food, being the basic grain for the planet's largest population. For tropical Asians it is the staple food and is the major source of dietary energy and protein. In Southeast Asia alone, rice is the staple food for 80 % of the population (Veena and Latharani, 2014).

2.8.2 Employment and Income Source

Rice is central to Ghana's economy and agriculture, accounting for nearly 15 percent of the total Gross Domestic Product (Bimpong, 1998). Rice production provides employment for a lot of rural dwellers (Berisavljevic *et al.*, 2003). Rice cultivation is the principal activity and source of income for about 100 million households in Asia and in Africa (Sanint *et al.*, 1998).

IRRI (2010) reported that the cultivation of rice is a source of income for millions of households around the globe, and several countries of Asia and Africa are highly dependent on rice as a source of foreign exchange earnings and government revenue.

2.8.3 Socio – Cultural Uses

The seeds of rice plant are used in folk medicine for breast cancers, tumours, warts and stomach indurations (Hartwell, 1967). Dried flowers of rice are as cosmetic in China. The awns of rice are used for treatment of jaundice in China (Duke and Ayensu, 1985).

The stem is used for billious conditions; ash for discharges and wounds, infusion of straw for dysentery and rheumatism. The husk is used for dysentery and considered tonic in China. Rice cakes are fried in camel's fat for hemorrhoids in China. The sprouts are used for poor appetite, dyspepsia (indigestion) chest and stomach pains in China (Reed, 1976).



2.8.4. By-products of Rice

Rice by-products include rice bran, rice polishing, rice bran oil and husk. Rice bran and rice polishing are used as animal feed. Rice bran oil is obtained from rice bran by solvent extraction. The oil is refined and used as cooking oil or salad oil. Rice husk contains about 20-20 % ash which is mostly silica. Rice husk is used as an abrasive and as a fuel (Sivasankar, 2010). Rice husk is used as bedding materials, and as source of energy. In the modern rice milling industry, rice husk is increasingly being used as a fuel source for grain drying and parboiling, and for electricity generation. In Bangladesh, rice hull is the preferred fuel for parboiling. Rice hull is widely used for grain drying in the larger rice mills in Northern India. Rice hull, once ground, is also used as ingredient in animal feeds (IRRI, 2010).

Using rice husk in gasifiers or furnaces that are used in small and medium size plants produces black ash which still contains around 20 % carbon. This so called carbonated rice husk is often used as soil conditioner for poor soils, as an ingredient for bio fertilizers (IRRI, 2010).

Rice bran has a high nutritive value. Besides proteins, rice bran is an excellent source of vitamins B and E. It also contains small amount of anti-oxidants, which are considered to lower cholesterol in humans. In recent years however, advances in stabilization techniques have been made which has led to new uses for bran and its derivatives, most notably bran oil for cooking and waxes for cosmetic products. In the developing countries, rice bran is underutilized due to a lack of suitable stabilization techniques (IRRI, 2010).

2.9 Rice Milling in Ghana

Rice mills in Ghana may be classified as small plant size mills (with less than 0.5 tonne per hour capacity), medium size mill (with capacity of up to 1 tonne per hour), or large mills (with



capacity of 1-4 tonnes per hour). In general, the milling out-put ratio of non-parboiled rice is about 50-60 %, where as that of parboiled paddy is about 70 % (Apori-Buabeng, 2009).

Paddy in its raw form cannot be consumed by human beings. It needs to be suitably processed for the kernel. Rice milling is the process which helps in removal of hulls and bran from paddy grains to produce polished rice. Rice forms the basic primary processed product obtained from paddy and this is further processed for obtaining various secondary and tertiary products. Milling, an important processing step of rough rice (paddy), is usually done to produce white and polished grain. A commercial rice milling system is a multi-stage process where the paddy is first subjected to dehusking and then to the removal of brownish outer layer, known as whitening (Yadav and Jindal, 2008).

A rice milling system can be a simple one or two step process, or a multi-stage process. In a one step milling process, husk and bran removal are done in one pass and milled or white rice is produced directly out of paddy. In a two step process, removing husk and removing bran are done separately, and brown rice is produced as an intermediate product. In multi-stage milling, rice will undergo a number of different processing steps. Depending on whether the paddy is milled in the village for local consumption or for the marketing, rice milling systems can be classified into the categories such as village rice mills and commercial mills (IRRI, 2010).

Furthermore, in Ghana, the milling techniques applied to locally produced rice vary considerably. Most of the processing is done manually especially by small rice producers (USAID, 2009), which in turn results in end products of different quality. The processed rice is brown in colour and with a lot of dirt particles. In Bolgatanga, in the Upper East region, however, the panicle is severed directly and much less extraneous matter gets into the processed



product. The resulting rice is white and can sometimes be passed as the imported type (Winrock International, 2009).

Quality improvement has been promoted but almost exclusively at the production and on-farm processing but significant investment in processing facilities would be needed to produce rice competitive with imported rice in quality (USAID, 2009).

According to consumer surveys undertaken in Ghana the quality of local or brown rice is very low. One of the main reasons why the majority of urban consumers do not buy local rice is that local rice is not fully clean from stones because of bad threshing. The local rice includes parboiled, white rice and brown rice and each has a market niche due to peculiar flavor and perceived nutritional qualities. The particularly low quality of domestically produced brown rice does not make it fully comparable to any of the two types of rice that are mainly imported in Ghana, broken and unbroken rice (USAID, 2009).

2.10 Rice milling processes

2.10.1 Pre Cleaning

When paddy comes into the mill, it contains foreign materials such as straw, weed seeds, soil and other inert materials. If these are not removed prior to hulling the efficiency of the huller and the milling recovery are reduced. Most pre-cleaners separate three groups of materials: The first separation is done by removing the objects that are larger than the grain. Either a flat oscillating screen or a rotary drum screen that allows the grain to pass through but retains straw can do this. The second separation retains the grains but allows broken grains, small stones and weed seeds to pass through. An air aspirator may also be incorporated to remove the dust and the light empty grains. Grain pre-cleaners can be classified according to their cleaning mechanism. These are:



1. Oscillating Sieve type

Oscillating sieve pre-cleaners are simple and often made locally. The machine consists of two sieves of different sizes depending on the size and shape of the grain. The top sieve has a slotted profile larger than the bottom and both screens can be changed to suit the grain size or crop type.

2. Aspiration cum Oscillation Type

The aspirator grain cleaner removes lighter impurities such as dust, dirt, chaff and straw by blowing or sucking air through the mass of falling grain and removing these light impurities in the air stream. Impurities that are not removed by the air are then separated from the grain using oscillating sieves. The sieving action of this machine is similar to the sieve oscillation cleaner. Some cleaners are also equipped with magnets to remove iron particles. Aspiration style cleaners can have either single or double action aspiration

3. Rotary Cleaner

This machine consists of one or two drums; each drum is fitted with mesh of different sized hexagonal or square perforation and an oscillating sieve. Foreign matter larger than the grain is removed as the paddy or rice passes through the drums. Paddy then flows onto the oscillating sieve to separate heavier impurities such as stone. There are two types of rotary cleaners: Single drum with aspirator and oscillation sieve. The single drum aspirator utilizes a single drum to separate large, light and heavy impurities. Lighter impurities are separated by suction aspiration and the oscillation sieves separate heavier impurities such as sand. The double drum with aspirator is a machine has two rotation drums with each drum having a different size hole on the wire mesh. It utilizes an aspirator to separate light impurities. This machine is typically used for cleaning freshly harvest paddy (IRRI, 2010).



2.10.2 De-stoning

This machine is the same as a single drum with aspiration and oscillating sieves but has an additional special arrangement for separating stones that have the same physical dimensions as paddy. Of particular importance is the direction of flow of the paddy compared to the direction of movement of the stones (IRRI, 2010).

2.10.3 Parboiling

Parboiling helps in improving the nutritional quality by gelatinization of starch inside the rice grain. It improves the milling recovery percentage during de-shelling and polishing or whitening operation. Despite the fact that the qualities desired in rice vary from one geographical region to another, the demand for parboiled brown rice has been increasing because of its reputation for nutritional excellence and the health claims associated with eating this type of rice. Parboiling is the hydrothermal treatment of paddy before milling, and it includes soaking, steaming and drying. The primary objective of parboiling is to improve the quality of rice and obtain a higher milling yield. The parboiled rice exhibits several advantages over the un-parboiled ones such as improved kernel strengthening, increased milling recovery and prevention of loss of nutrients associated with milling, and improved shelf life. It is suggested that parboiling helps fill the void spaces and cement the cracks inside the endosperm, making the grain harder and minimizing internal fissuring and thereby reducing breakages during milling. From the economic point of view, the quality of milled rice is of paramount importance since grain size and shape, whiteness and cleanliness are strongly correlated with the transaction price of rice, while the presence of broken grains mostly half the market value of head rice (Oyedele and Adeoti, 2013).





Parboiling rice is a process that takes its origins in south India. It mainly consists of soaking the rice grains with the husk still on, then cooking them with steam before eventually drying them and milling them. Soaking the grains causes them to swell and helps essential nutrients, such as thiamine, to migrate from the bran of the grain where they are normally found to the kernel of the grain. This will result in more nutritious rice than white rice and more digestible rice than brown rice. Steaming or treating the rice with heat causes the starch to gelatinize. Subsequently, the rice temperature and moisture content are gradually reduced during the drying stage in order to minimize the stress from the heat applied to the rice. During drying, the rice endosperm hardens which in turns gives a grain that is firmer, easier to dehusk and subject to less breakage when milled. This translates into a better milling yield for millers and into a more separate grain that withstands long cooking times without becoming undesirably sticky for consumers. Parboiling processes can be affiliated to three major categories. The conventional method is constituted of the following sequence of events: soaking, draining, steaming at atmospheric pressure, drying and finally milling. The second method, called the dry-heat method, is in essence the same as the previous one except that it replaces steaming with a heating stage, in which the rice is cooked in dry, hot air or sand prior to drying. The third method that is broadly used is called the pressure-steaming parboiling. In this method, soaking is followed by pressurized steaming prior to final steps of drying and milling (Riceland International, 2011).

2.10.4 Husk Aspiration

The husk layer is removed from the paddy by friction and the process is called either de-husking or de-hulling. De-husking was traditionally done using mortar and pestles but, in modern rice mills, it is done by passing the paddy grains between two abrasive surfaces that are moving at

different speeds. After separating the husk and paddy, the husk is removed by suction (aspirated) and then transported to a storage dump outside the milling plant. The percentage of paddy that is de-hulled to produce brown rice during this process is called the hulling efficiency. An efficient husker will remove 90 % of the husk in a single pass. After the husk has been removed the brown rice goes to a paddy separator. The kernels that were not de-husked in the first pass will be separated and then returned to the de-husker. The de-husker can be a steel huller, under rubber disc sheller or rubber roller huller. The steel huller removes the husks and whitens the rice in one pass. Paddy rice is fed into the machine and passes between a revolving steel shaft and a cylindrical shaped mesh screen. These machines are normally powered by a 15 to 20 hp engine and are very simple to operate. They are relatively cheap. The under-runner husker is very common in Asia. This machine has two steel discs, which have an emery coating. The upper disc is stationary and fixed to the cast iron housing. Paddy flows from a centrally located hopper between the abrasive surfaces of the revolving lower disc and the stationary upper disc. Resistance between the emery surface on the discs and the paddy grains removes the husk leaving the brown rice kernel. Brown rice and husks are then discharged circumferentially over the revolving disc and exit through an outlet. This machine is very economical to run, produces a moderate amount of cracked or broken grain, and has a hulling efficiency of about 85-90 %.



The rubber-roller huller is the most efficient hulling machine. As the name suggests two rubber rollers of the same diameter are operated at different speeds to remove the husk from the paddy. One roller has a fixed position and the other is adjustable to meet the desired clearance. The adjustable roller rotates slightly slower than the fixed roller. Rubber-roll hullers have an aspirator in the base of the machine to separate the hulls from the brown rice. The roll diameter varies

from 150 to 250 mm and the roller width from 60 to 250 mm. The correct clearance is dependent on the varietal characteristics and the width and length of paddy. This method of hulling can achieve hulling efficiencies of 85 % to 90 % with minimum broken or cracked grain. This type of machine is now widely used in developed countries (IRRI, 2010).

2.10.5 Paddy Separation

The output from the huller is a mixture of paddy rice, brown rice, husk, broken paddy, and sometimes bran. The huller aspirator removes the lighter material such as husk, bran and very small broken. The remainder passes onto the paddy separator where the unhulled paddy rice is separated from the brown rice. The amount of paddy present depends on the efficiency of the husker, and should not be more 10 %. Paddy separators work by making use of the differences in specific gravity, buoyancy and size between paddy and brown rice. Paddy rice has a lower specific gravity, higher buoyancy, and is physically bigger, longer and wider than brown rice. There are two types of paddy separators, compartment separator and the tray separator. The compartment type of paddy separator uses the difference in specific gravity and the buoyancy to separate paddy and brown rice. When paddy and brown rice move over an inclined plane, they move at different speeds depending on their specific gravity, their shape and contact area, smoothness of inclined surface and the co-efficient of sliding friction. Brown grains are smaller, heavier, rounder and smoother and will slide faster than paddy grains. The processing capacity of the compartment separator is dependent on the compartment area. For a 2-tonne/hr capacity rice mill, a 45-compartment separator made up of 15 compartments on each of three decks is used. The tray separator uses the differences in specific gravity, grain length and the co-efficient of friction to separate paddy and brown rice. The oscillation and slope of the tray forces the brown



rice to move up the slope and the paddy to slide down. The separation performance of this type of paddy separator is very good. This machine is very compact, easy to adjust, and consumes less power than the compartment type separator (IRRI, 2010).

2.10.6 Whitening or polishing process

White rice is produced from brown rice by removing the bran layer and the germ. The bran layer is removed from the kernel by applying friction to the grain surface either by rubbing the grains against an abrasive surface or against each other. The amount of bran removed is normally between 8-10 % of the total paddy weight but this will vary according to the variety and the degree of whiteness required. The process used to whiten brown rice can be classified as either abrasive or friction. In the abrasive process, the grain is whitened by the abrasive action of the rice kernel passing between a moving abrasive surface and stationary screen. The hard rough surface is usually stone or a carborundum type material. The abrasive process applies less pressure on the grain and is better suited for long grain varieties. Abrasive polishers can be either vertical or horizontal in design. The vertical cone whitener is very common in many Asian countries. In the friction whitener, the grain kernels are forced against each other and a metal screen by a steel-ribbed cylinder rotating inside a metal-plated cylinder. The frictional forces created between individual rice grains and between the grains and the metal screen surface remove the bran layer from the grain. Friction polishers are always horizontal in design and apply more pressure on the grain than an abrasive whitener (IRRI, 2010).



2.10.7 Length Grading

After polishing, the white rice is separated into head rice and, large and small broken rice by a sifter. Head rice is normally classified as kernels, which are 75-80 % or more of a whole kernel. The sifter is made up of a series of oscillating screens through which the rice passes. The output from the bottom screen is the very fine broken tips and is called the “brewers”. To attain a higher degree of precision for grading and separation, a length or indent grader is also used. This machine is made up of 1-3 rotating indented cylinders. The broken and smaller rice pieces fall into the indents on the rotating roller surface and are removed leaving the whole rice kernels or head rice (IRRI, 2010).

2.10.8 Blending

A good rice mill will produce 50-60 % head rice (whole kernels) 5-10 % large broken and 10-15 % small broken kernels. Depending on the country’s standards, rice grades in the market will contain from 5-25 % broken kernels. If rice mixing is to be done properly a volumetric mixer is necessary. Mixing a fine mist of water with the dust retained on the whitened rice improves the luster of the rice (polishes) without significantly reducing the milling yield. A friction type-whitening machine, which delivers a fine mist of water during the final whitening process, is used for “final” polishing before sale (IRRI, 2010).

2.10.9 Weighing and bagging

Rice is normally sold as 50 kg sacks which must be accurately weighed and labeled. While most rice mills use a manual- mechanical weighing system, very accurate and fast electronic systems are also available (IRRI, 2010).



2.11 Importance of Measuring Moisture Content of Paddy.

Moisture Content (MC) is the weight of water contained in paddy or rice expressed in percentage. Moisture content is usually referred to on the wet basis, meaning the total weight of the grain including the water (MC_{wb}). Accurate moisture content testing is important in managing and marketing paddy and rice. Inaccurate moisture content measurements lead to:

- Extra drying cost and harvesting loss if paddy is harvested wetter than necessary
- Spoilage if the grain is too wet in storage
- Extra drying cost and loss of quality if paddy is too dried
- Lower head rice yield when milled at wrong MC
- Weight loss (loss in profit) if grain is sold too dry

Methods of measuring moisture contents are mainly: primary method and secondary method. The most exact method only uses weight measurements and is therefore called primary method. Rice with certain moisture content is weighed, and then the water is evaporated from the sample using heated air until no weight change is observed anymore, and the remaining "dry matter" is weighed again. The moisture content is then calculated. Since weight measurements are very exact this so called "oven method" is usually used as the reference method for scientific trials.

The moisture content of the sample is calculated using the following equation:

$$\% W = \frac{A-B}{A} \times 100 \%$$

Where:

% W = Percentage of moisture in the sample,



A = Weight of wet sample (grams), and

B = Weight of dry sample (grams)

Secondary methods measure either the electrical resistance or di-electrical properties of paddy using electronic instruments. These methods produce results within seconds or minutes and are therefore usually used in postharvest management and for trade. For measuring moisture content in harvesting, the most practical option is a resistance type moisture meter that gives quick results and only uses small samples. Capacitive moisture meters are more expensive, and more accurate than resistance type units. Paddy is harvested at optimum grain maturity at which the grains have an average moisture content of 20-25 %. Higher moisture content results in more losses from poor grain quality. Lower moisture content results in more losses from shattering. For safe storage, grains need to be dried to below 14 % and seeds should be dried to below 12 %. Ideal moisture content for milling is between 12-14 %, depending on the type of variety (IRRI, 2010).

Moisture content has a marked influence on all aspects of paddy and rice quality and it is essential that paddy be milled at the proper moisture content to obtain the highest head rice yield. Paddy is at its optimum milling potential at moisture content of 14 % (wet weight basis). Grains with high moisture content are too soft to withstand hulling pressure which results in grain breakage and possibly pulverization of the grain. Grain that is too dry becomes brittle and has greater breakage. Moisture content and temperature during the drying process is also critical as it determines whether small fissures and or full cracks are introduced into the grain structure (IRRI, 2010). In agriculture, moisture level in grain such as paddy is measured to control the quality of products and facilitate in research and development.



2.12 Broken rice grain

Kernel breakage during milling process is a major concern in rice producing countries. As a common rule, milled rice kernel longer than 75 % of a whole kernel is known as head rice; otherwise identified as broken kernel (Thakur and Gupta, 2006). Less mechanical resistance of rice kernels in milling operation is the key factor for milled rice breakage. The market value of rough rice is mainly based on its milling yield or on its milling quality. The milling yield is determined from the quantity of whole kernels (head rice) and broken kernels produced during the milling of rough rice. Therefore, head, broken and total milled rice are usually expressed as a percentage of the total quantity of the rough rice subjected to the milling procedure (Ntanos *et al.*, 1996).

Milled rice economic value is dependent on the proportion of broken rice kernels in the bulk (Monsoor *et al.*, 2004). Kernel moisture content during drying causes fissures and cracks and eventually breakage during rice milling (Lloyd and Siebenmorgen, 1999; Siebenmorgen and Jindal, 1986; Siebenmorgen *et al.*, 1998). From the chemical standpoint, although broken and whole rice kernels have similar starch yields and protein contents, broken kernels have been reported to have significantly greater soluble lipid content and rate of lipid hydrolysis than whole kernels (Monsoor and Proctor, 2003; Wang *et al.*, 2002).

Paddy with high moisture content leads to development of fissures and cracks in individual kernel. Cracks in the kernel are the most important factor contributing to rice breakage during milling. This will result in reduced milled rice recovery and head rice yields.



2.13 Head Rice

Head rice or head rice percentage is the weight of head grain or whole kernels in the rice lot. Head rice normally includes broken kernels that are 70-80 % of the whole kernel. High head rice yield is one of the most important criteria for measuring milled rice quality. Broken grain has normally only half of the value of head rice. The actual head rice percentage in a sample of milled rice will depend on both varietal characteristics (i.e. the potential head rice yield), production factors and harvesting, drying and milling process (IRRI, 2010). Head Rice Yield (HRY) is one of the most important parameters in determining the economic and processing value of rice crop. It is defined as the mass percentage of rough rice kernels that are at least three-quarters their original kernel length after milling.

2.14 Milling degree

The degree of milling is a measure of the percent bran removed from the brown rice kernel. Milling degree affects milling recovery and influences consumer acceptance. Apart from the amount of white rice recovered, milling degree influences the colour and also the cooking behavior of rice. Brown rice absorbs water poorly and does not cook as quickly as the polished rice (IRRI, 2010).



CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The research was conducted in a laboratory at Ashaiman Irrigation Project site in Accra. The irrigation project started in 1965 and completed in 1968. It has a potential area of 155 ha with an irrigated area of 56 ha. The irrigation type is gravity. It is precisely located between coordinates 5° 40' and 5° 43' N of latitude and longitudes 0° 05' and 0° 07' E at a distance of 26 km North East of Accra and almost directly North of Tema on the Northern boundaries of Tema township in the Greater Accra Region of Ghana. The Climate is Coastal Savannah type. The source of water for irrigation is a reservoir, which is fed by Dzorwulu stream and run-off water from the catchment area. The project serves as a research centre which attracts institutions, Non-Governmental Organisations and other individuals. Farmers at the project site produce rice seeds for the Ministry of food and Agriculture to be distributed to some farmers in the country which makes the Scheme beneficial to the country (MoFA, 2015).

3.2 Materials and Laboratory Equipment

The following laboratory equipment and materials were used for the experimental investigation:

Milling machine

Model: THU-35, Satake Hiroshima, Japan

Power (kW): 0.2-0.4

Capacity: 50-500 g / min

This machine was used to mill the paddy samples.



Polisher

Model: Satake Tekko

Power (kW): 0.41-0.46

Capacity: 500 g / 5 min

This machine was used to remove the bran layer of the brown rice.

Grader

Model: Satake Test Rice Grader TRC 0.5 A

Capacity: 500 g / 3 min

This was used to separate white rice into head and broken grains.

Moisture meter

Model: Grain Moisture Tester, Riceter J301

Range: 9- 30 %

This was used to measure the moisture contents of the paddy samples before milling.

Electronic scale

Model: LIBROR EB-32000

Capacity: 3120.0 g x 600.00 g

This was used to measure the weight of paddy and milled rice.

Sacks

Type: Polythene bags

Size: 23 cm x 16.5 cm

The sacks were used to contain paddy and milled rice during weight measurement.



Three rice varieties

Six (6) kg each of three rice varieties namely: Gbewaa, Digang and Nabogu were collected from CSIR/SARI, Nyankpala, as paddy samples. The seeds were sent to Ashaiman Irrigation Project's laboratory for the milling processes and subsequent determination of the physical quality characteristics of the milled rice.

3.3 Sampling and Sample preparation

Six (6) kg paddy samples each of the three varieties were parboiled and sun-dried in drying trays. They were constantly turned and mixed to achieve rapid-uniform drying. During the turning and mixing process, the moisture content was also taken until the 14 %, 12 % and 10 % moisture contents were achieved. Five hundred grams (500 g) of paddy each of the three varieties was milled in triplicates for the three moisture content levels using Satake dehusking machine. The weights of brown rice and husk were taken using an electronic scale. Brown rice was polished using Satake polishing machine. The weights of white rice and bran were recorded. White rice was sent to Satake grading machine where it was separated into head rice and broken rice. The weights of head rice, brown rice, husk, bran and broken rice were taken and calculations done based on IRRI (2010) formulae.

3.4 Determination of some physical quality characteristics of milled rice

The following parameters were measured based on IRRI formulae (IRRI, 2010):

3.4.1 Brown rice

This is the weight of milled rice (including broken) obtained from a sample of paddy.

$$\text{Brown rice} = \frac{\text{wt of brown rice (g)}}{\text{wt of paddy (g)}} \times 100 \%$$



3.4.2 Husk

This is the weight of husks obtained from a sample of paddy.

$$\text{Husk} = \frac{\text{wt of husk (g)}}{\text{wt of paddy (g)}} \times 100 \%$$

3.4.3 Bran

This is the weight of bran obtained from the brown rice kernel.

$$\text{Bran} = \frac{\text{wt of bran (g)}}{\text{wt of paddy (g)}} \times 100 \%$$

3.4.4 Head grain

This is the weight of head grain obtained from the milled rice. Head grain normally includes broken grains that are 75-80 % of the whole kernel.

$$\text{Head grain} = \frac{\text{wt of head grain (g)}}{\text{wt of paddy (g)}} \times 100 \%$$

3.4.5 Broken grain

This is the weight of broken grain obtained from the milled rice.

$$\text{Broken grain} = \frac{\text{wt of broken grain (g)}}{\text{wt of paddy (g)}} \times 100 \%$$

3.5 Data processing

Data were processed using the computer programme Minitab® 16.2.2 (Minitab Inc., State College, PA, USA). Least Significant Difference (LSD) of $p < 0.05$ was used. Results of the analysis were presented in tables and graphs.



CHAPTER FOUR

4.0 RESULTS

Tables and graphs have been presented to explain the results of the experiments.

4.1 Percentage presentation of the physical quality characteristics of different rice varieties milled at different moisture contents

4.1.1 Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 14 % moisture content

Table 3 shows the values of the parameters determined in the milling of Gbewaa rice at 14 % moisture content. The brown rice yield obtained is in the range of 77.18 % -77.48 %.

Table 3: Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 14 % moisture content

Replication	Moisture content (%)	Rice variety	Brown rice yield (%)	White rice yield (%)	Head rice yield (%)	Broken rice yield (%)	Rice bran yield (%)	Rice husk yield (%)
1	14	Gbewaa	77.36	71.30	54.40	16.90	6.06	22.64
2	14	Gbewaa	77.18	70.80	55.50	15.30	6.38	22.82
3	14	Gbewaa	77.48	72.14	56.52	15.62	5.34	22.52

4.1.2 Percentage presentation of the physical quality characteristics of Nabogu rice milled at 14 % moisture content

Table 4 shows the values of the parameters determined in the milling of Nabogu rice at 14 % moisture content. The brown rice yield obtained is in the range of 77.74 % -77.82 %. White rice,



head rice, broken rice, bran and husk yields were in the ranges of: 71.14 % -71.88 %, 61.62 % - 62.08 %, 9.22 % -9.80 %, 5.74 % -6.68 % and 22.18 % -22.38 % respectively.

Table 4: Percentage presentation of the physical quality characteristics of Nabogu rice milled at 14 % moisture content

Replication	Moisture content (%)	Rice variety	Brown rice yield (%)	White rice yield (%)	Head rice yield (%)	Broken rice yield (%)	Rice bran yield (%)	Rice husk yield (%)
1	14	Nabogu	77.82	71.14	61.62	9.52	6.68	22.18
2	14	Nabogu	77.62	71.88	62.08	9.80	5.74	22.38
3	14	Nabogu	77.74	71.48	62.26	9.22	6.26	22.26

4.1.3 Percentage presentation of the physical quality characteristics of Digang rice milled at 14 % moisture content

Table 5 shows yield values obtained from the Digang rice variety at 14 % moisture content. At this moisture content, the brown rice ranged between 76.20 % and 76.56 %. White rice, head rice, broken rice, bran and husk yields were in the ranges of 69.72 % - 70.34 %, 46.14 % - 47.80 %, 21.92 % -23.80 %, 6.20 % -6.62 % and 23.44 % -23.80 % respectively.

Table 5: Percentage presentation of the physical quality characteristics of Digang rice milled at 14 % moisture content

Replication	Moisture content (%)	Rice variety	Brown rice yield (%)	White rice yield (%)	Head rice yield (%)	Broken rice yield (%)	Rice bran yield (%)	Rice husk yield (%)
1	14	Digang	76.56	69.94	46.14	23.80	6.62	23.44
2	14	Digang	76.54	70.34	47.40	22.94	6.20	23.46
3	14	Digang	76.20	69.72	47.80	21.92	6.48	23.80



4.1.4 Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 12 % moisture content

Table 6 shows yield values obtained from the Gbewaa rice variety at 12 % moisture content. At this moisture content, the brown rice ranged between 75.04 % and 75.54 %. White rice, head rice, broken rice, bran and husk yields were in the ranges of 66.80 % -69.06 %, 39.82 % -41.88 %, 26.68 % -27.18 %, 8.24 % -8.52 % and 24.46 % -24.96 % respectively.

Table 6: Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 12 % moisture content

Replication	Moisture content (%)	Rice variety	Brown rice yield (%)	White rice yield (%)	Head rice yield (%)	Broken rice yield (%)	Rice bran yield (%)	Rice husk yield (%)
1	12	Gbewaa	75.42	66.90	40.22	26.68	8.52	24.58
2	12	Gbewaa	75.54	69.06	41.88	27.18	8.48	24.46
3	12	Gbewaa	75.04	66.80	39.82	26.98	8.24	24.96

4.1.5 Percentage presentation of the physical quality characteristics of Nabogu rice milled at 12 % moisture content

Table 7 shows yield values obtained from Nabogu rice variety at 12 % moisture content. At this moisture content, the brown rice ranged between 76.78 % and 77.54 %. White rice, head rice, broken rice, bran and husk yields were in the ranges of: 69.62 % -71.20 %, 53.72 % -55.04 %, 15.16 % -16.60 %, 6.34 % -7.70 % and 22.46 % -23.22 % respectively.



Table 7: Percentage presentation of the physical quality characteristics of Nabogu rice milled at 12 % moisture content

Replication	Moisture content (%)	Rice variety	Brown rice yield (%)	White rice yield (%)	Head rice yield (%)	Broken rice yield (%)	Rice bran yield (%)	Rice husk yield (%)
1	12	Nabogu	76.78	70.32	53.72	16.60	6.46	23.22
2	12	Nabogu	77.32	69.62	54.46	15.16	7.70	22.68
3	12	Nabogu	77.54	71.20	55.04	16.28	6.34	22.46

4.1.6 Percentage presentation of the physical quality characteristics of Digang rice milled at 12 % moisture content

Table 8 shows yield values obtained from the Digang rice variety at 12 % moisture content. At this moisture content, the brown rice ranged between 77.68 % and 78.66 %. White rice, head rice, broken rice, bran and husk yields were in the ranges of 68.42 % -69.22 %, 37.60 % -39.80 %, 29.22 % -31.62 %, 8.66 % -10.16 % and 21.34 % -22.32 % respectively.

Table 8: Percentage presentation of the physical quality characteristics of Digang rice milled at 12 % moisture content

Replication	Moisture content (%)	Rice variety	Brown rice yield (%)	White rice yield (%)	Head rice yield (%)	Broken rice yield (%)	Rice bran yield (%)	Rice husk yield (%)
1	12	Digang	77.68	69.02	39.80	29.22	8.66	22.32
2	12	Digang	78.58	68.42	37.92	30.50	10.16	21.42
3	12	Digang	78.66	69.22	37.60	31.62	9.44	21.34



4.1.7 Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 10 % moisture content

Table 9 shows yield values obtained from the Gbewaa rice variety at 10 % moisture content. At this moisture content, the brown rice ranged between 75.56 % and 76.16 %. White rice, head rice, broken rice, bran and husk yields were in the ranges of 67.44 % -68.10 %, 33.00 % -38.32 %, 29.12 % -35.10 %, 7.46 % -8.60 % and 23.84 % -24.44 % respectively.

Table 9: Percentage presentation of the physical quality characteristics of Gbewaa rice milled at 10 % moisture content

Replication	Moisture content (%)	Rice variety	Brown rice yield (%)	White rice yield (%)	Head rice yield (%)	Broken rice yield (%)	Rice bran yield (%)	Rice husk yield (%)
1	10	Gbewaa	76.16	67.56	36.00	31.56	8.60	23.84
2	10	Gbewaa	75.72	67.44	38.32	29.12	8.28	24.28
3	10	Gbewaa	75.56	68.10	33.00	35.10	7.46	24.44

4.1.8 Percentage presentation of the physical quality characteristics of Nabogu rice milled at 10 % moisture content

Table 10 shows yield values obtained from the Nabogu rice variety at 10 % moisture content. At this moisture content, the brown rice ranged between 78.12 % and 79.20 %. White rice, head rice, broken rice, bran and husk yields were in the ranges of 73.78 % -74.78 %, 56.30 % -58.28 %, 15.50 % -18.48 %, 4.34 % -5.42 % and 20.80 % - 20.88 % respectively.



Table 10: Percentage presentation of the physical quality characteristics of Nabogu rice milled at 10 % moisture content

Replication	Moisture content (%)	Rice variety	Brown rice yield (%)	White rice yield (%)	Head rice yield (%)	Broken rice yield (%)	Rice bran yield (%)	Rice husk yield (%)
1	10	Nabogu	79.12	74.78	56.30	18.48	4.34	20.88
2	10	Nabogu	79.20	74.68	58.22	16.46	4.52	20.80
3	10	Nabogu	78.12	73.78	58.28	15.50	5.42	20.80

4.1.9 Percentage presentation of the physical quality characteristics of Digang rice milled at 12 % moisture content

Table 11 shows yield values obtained from the Digang rice variety at 10 % moisture content. At this moisture content, the brown rice ranged between 78.06 % and 78.24 %. White rice, head rice, broken rice, bran and husk yields were in the ranges of 73.36 % -74.04 %, 40.98 % - 41.78 %, 32.2 % -32.38 %, 4.20 % -4.70 % and 21.76 % -21.94 % respectively.

Table 11: Percentage presentation of the physical quality characteristics of Digang rice milled at 10 % moisture content

Replication	Moisture content (%)	Rice variety	Brown rice yield (%)	White rice yield (%)	Head rice yield (%)	Broken rice yield (%)	Rice bran yield (%)	Rice husk yield (%)
1	10	Digang	78.12	73.72	41.38	32.34	4.40	21.88
2	10	Digang	78.06	73.36	40.98	32.38	4.70	21.94
3	10	Digang	78.24	74.04	41.78	32.26	4.20	21.76



4.1.10 Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 14 % moisture content

Table 12 shows the average values from the three rice varieties analysed at 14 % moisture content. The results showed that Digang rice had the least brown rice yield whilst Nabogu rice had the highest. Nabogu rice also recorded higher white rice and head rice yields than that of Gbewaa and Digang rice varieties. Digang rice had the highest broken rice and bran yields whilst Nabogu rice had the least.

Table 12: Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 14 % moisture content

Replication	Moisture content (%)	Rice variety	Average brown rice yield (%)	Average white rice yield (%)	Average head rice yield (%)	Average broken rice yield (%)	Average rice bran yield (%)	Average rice husk yield (%)
1	14	Gbewaa	77.3	71.4	55.5	15.9	5.93	22.7
2	14	Nabogu	77.7	71.5	62.0	9.5	6.23	22.3
3	14	Digang	76.4	70.0	47.1	22.89	6.43	23.6

4.1.11 Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 12 % moisture content

Table 13 shows the average values from the three rice varieties analysed at 12 % moisture content. The results showed that Gbewaa rice had the least brown rice yield whilst Digang rice had the highest. Nabogu rice also recorded higher white rice and head rice yields than that of Gbewaa and Digang rice varieties. Digang rice had the highest broken rice and bran yields whilst Nabogu rice had the least.



Table 13: Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 12 % moisture content

Replication	Moisture content (%)	Rice variety	Average brown rice yield (%)	Average white rice yield (%)	Average head rice yield (%)	Average broken rice yield (%)	Average rice bran yield (%)	Average rice husk yield (%)
1	12	Gbewaa	75.3	67.59	40.64	26.95	8.41	24.7
2	12	Nabogu	77.2	70.38	54.41	16.01	6.83	22.8
3	12	Digang	78.3	68.89	38.44	30.45	9.42	21.7

4.1.12 Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 10 % moisture content

Table 14 shows the average values from the three rice varieties analysed at 10 % moisture content. The results showed that, Gbewaa rice had the least brown rice yield whilst Nabogu rice had the highest. Nabogu rice also recorded higher white rice and head rice yields than that of Gbewaa and Digang rice varieties. Digang rice had the highest broken rice yield whilst Nabogu rice had the least. Gbewaa rice had the highest bran and husk yields whilst Digang rice had the least bran yield and Nabogu rice had the least husk yield.

Table 14: Average percentage presentation of the physical quality characteristics of Gbewaa, Nabogu and Digang rice milled at 12 % moisture content

Replication	Moisture content (%)	Rice variety	Average brown rice yield (%)	Average white rice yield (%)	Average head rice yield (%)	Average broken rice yield (%)	Average rice bran yield (%)	Average rice husk yield (%)
1	10	Gbewaa	75.81	67.70	35.77	31.93	8.11	24.19
2	10	Nabogu	79.17	74.41	57.60	16.81	4.76	20.83
3	10	Digang	78.19	73.70	41.38	32.33	4.43	21.86



4.2 Brown rice yield as influenced by moisture content and variety

The study revealed that there were significant differences (at $p < 0.05$) in brown rice yield relative to the varieties and the moisture contents (Figure 1). At the 10 % moisture content, Nabogu rice variety recorded the highest average yield (395.87 g) and Gbewaa rice variety had the lowest average yield (379.07 g). At 12 % moisture content, Digang rice variety recorded the highest average yield (391.53 g) whilst Gbewaa rice variety recorded the lowest yield (376.67 g). However, at the 14 % moisture content, Digang rice variety recorded the highest average brown rice yield (391.53 g) whilst Gbewaa rice variety recorded the lowest yield (376.67 g). However, at the 14 % moisture content, Digang rice variety had the lowest average yield (382.17 g), whilst Nabogu rice variety had the highest yield (388.63 g). There were significant differences in brown rice yield among the interactions between moisture content and variety.

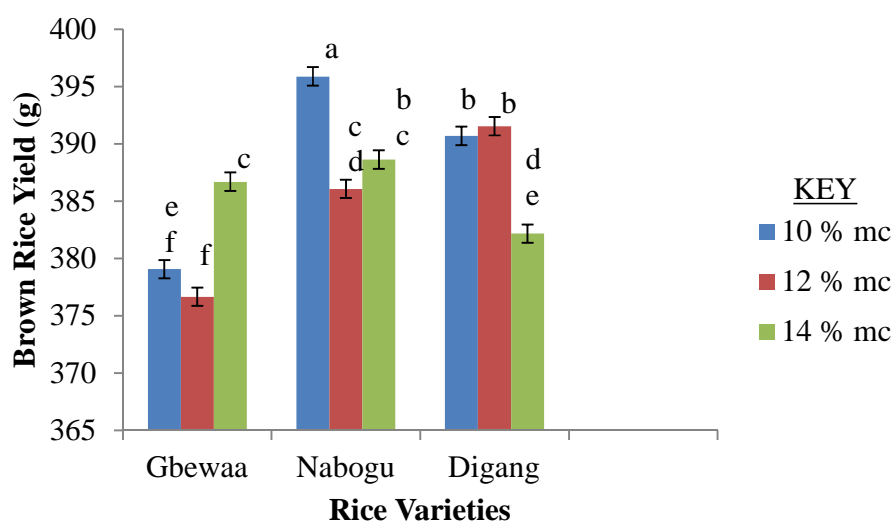


Figure 1: Brown rice yield as influenced by moisture content and variety

4.3 White rice yield as influenced by moisture content and variety

The results of white rice yield as shown in Figure 2 indicated that there were significant differences ($p < 0.05$) among all the three rice varieties (Gbewaa, Nabogu and Digang) at the 10



% and the 12 % moisture contents, with the exception of Gbewaa rice at the 14 % moisture content. Nabogu and Digang rice varieties recorded higher white rice yield at the 10 % moisture content, with Nabogu rice variety recording the highest average yield (372.07 g). Nabogu rice variety was 33.5 g more than Gbewaa rice variety which had the least average white rice yield (338.57 g) among all the three rice varieties at all the three different moisture contents.

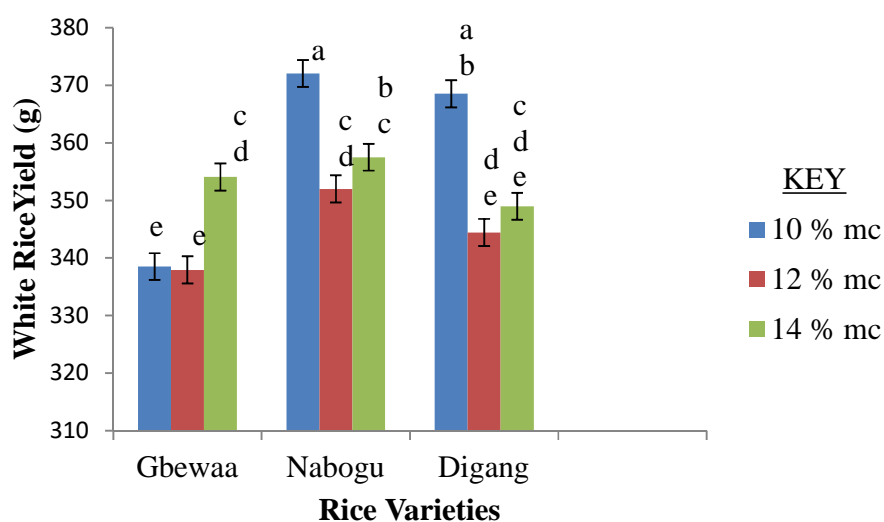


Figure2: White rice yield as influenced by moisture content and variety

4.4 Broken grain yield as influenced by moisture content and variety

There were significant differences ($p < 0.05$) among the three rice varieties considered in this investigation as indicated in Figure 3. It was clear that at the 10 % moisture content, all the three rice varieties recorded high broken grains, with Digang rice variety having the highest average broken grains (161.63 g). Nabogu rice variety recorded the least (47.57 g) at the 14 % moisture content. At the 14 % moisture content, Digang rice variety recorded the highest average broken rice grains (114.43 g), followed by Gbewaa rice variety. Nabogu rice variety which had the least



broken rice grains was more than two fold lower than Digang rice variety and Gbewaa rice variety at all the moisture contents (14 %, 12 % and 10 %).

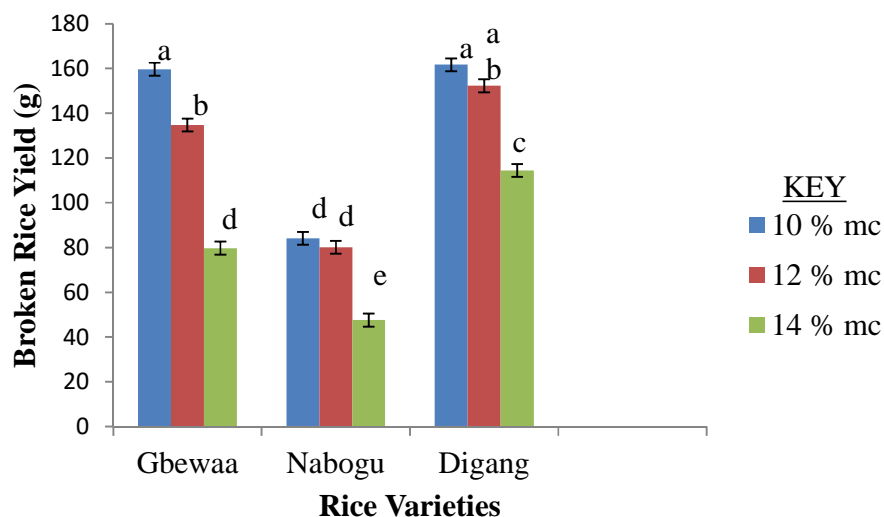


Figure 3: Broken grain yield as influenced by moisture content and variety

4.5 Head rice yield as influenced by moisture content and variety

The results of head rice yield as shown in Figure 4 revealed that there were significant differences ($p < 0.05$) among almost all the three rice varieties at the three moisture contents (14 %, 12 % and 10 %). Generally, all the three rice varieties had higher head rice yields at the 14 % moisture content, with Nabogu rice variety having the highest average yield (307.60 g). Gbewaa rice variety also had better head rice yield than Digang rice variety at that same 14 % moisture content. Digang rice variety had the least average head rice yield (206.9 g) at the 10 % moisture content. At 12 % moisture content, the highest head rice yield was again observed in Nabogu rice variety (272.03 g), with Digang rice having the least head rice yield.



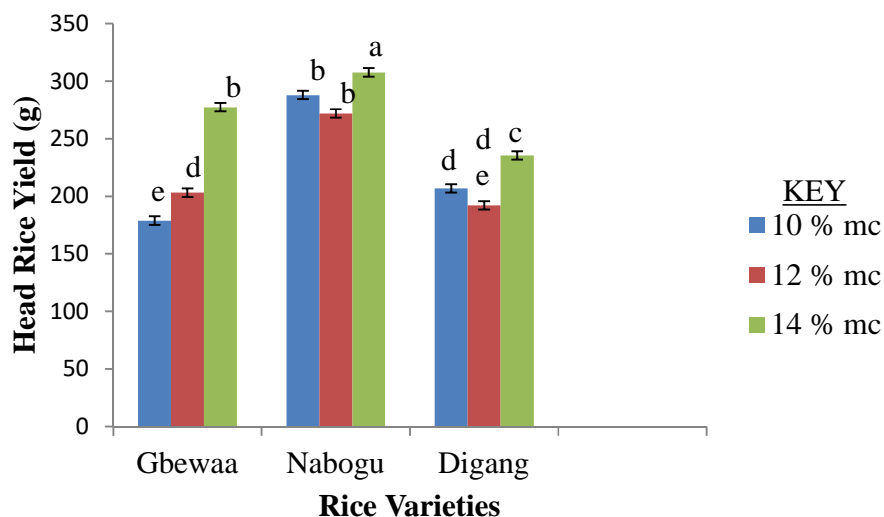


Figure 4: Head rice yield as influenced by moisture content and variety

4.6 Rice bran yield as influenced by moisture content and variety

The results showed that there were significant differences ($p < 0.05$) in almost all the three rice varieties at 10 % and 14 % moisture contents as shown in Figure 5. Digang rice variety recorded the highest average rice bran yield (47.03 g) at the 12 % moisture content and had the least average rice bran yield (22.17 g) at the 10 % moisture content. It was two folds higher at the 12 % moisture content than it was at the 10 % moisture content. Gbewaa rice variety which recorded an average rice bran yield of (40.57 g) was also higher than Nabogu rice variety (23.8 g) at the 10 % moisture content. Nabogu rice variety was also averagely higher in rice bran (31.13 g) than Gbewaa rice variety (29.63 g) at the 14% moisture content.



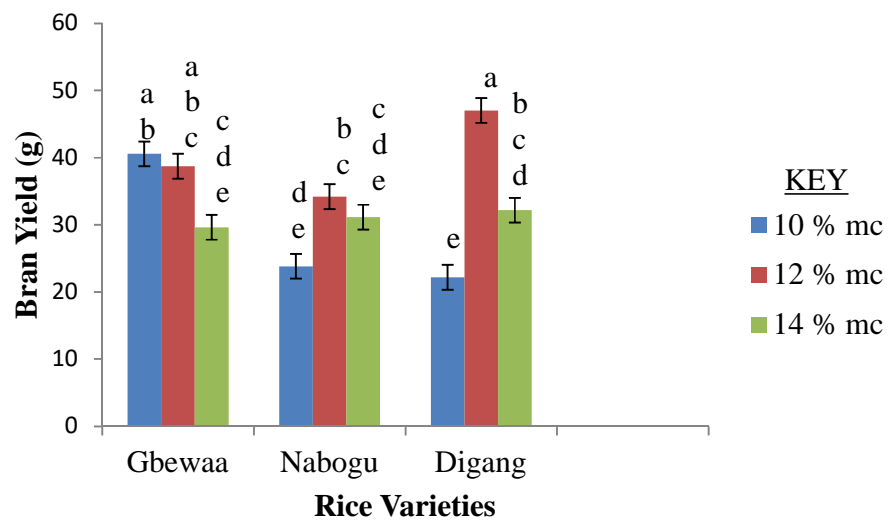


Figure 5: Rice bran yield as influenced by moisture content and variety



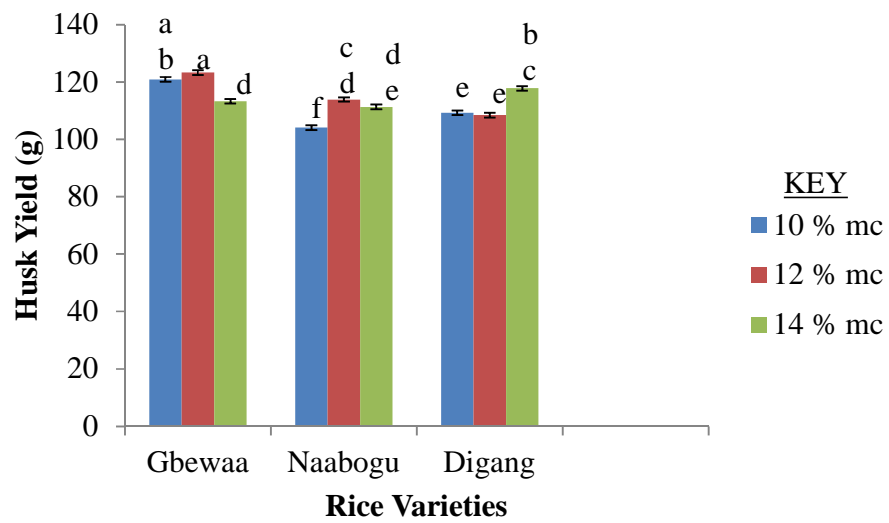


Figure 6: Rice husk yield as influenced by moisture content and variety



4.7 Rice husk yield as influenced by moisture content and variety

Figure 6 shows the husk yields from the rice varieties in relation to the moisture contents. From Figure 6, it is shown that there were significant differences in rice husk yield against all the three rice varieties and at the moisture contents (14 %, 12 % and 10 %). Gbewaa rice variety had the highest average husk yield (123.33 g) at the 12 % moisture content, followed by Nabogu rice variety; with Digang rice variety recording the least (108.47 g). On the other hand, Digang rice variety had the highest average rice husk yield (117.83 g) at the 14 % moisture content, followed by Gbewaa rice variety; with Nabogu rice variety recording the least (111.37 g). Gbewaa rice variety had the highest average rice husk yield at the 10 % moisture content (120.93 g) and Nabogu rice variety recorded the least average husk yield of 104.13 g.



CHAPTER FIVE

5.0

DISCUSSION

5.1 Moisture and variety effects on brown rice yield

The yield of brown rice is the weight of milled rice (including broken) obtained from a sample of paddy.

The outcome of this study revealed that brown rice yield of Nabogu rice variety was the highest at the 10 % moisture content (Figure 1). The reason for this outcome could be that Nabogu rice variety has lighter husk layer than that of Gbewaa and Digang rice varieties. The average percentage yields of brown rice at the 12 % moisture content were 75 %, 77 % and 78 % for Gbewaa rice, Nabogu rice, and Digang rice varieties respectively. They were 77 %, 77 % and 76 % at the 14 % moisture content and 75.82 %, 79.17 % and 78.19 % at the 10 % moisture content. This finding disagrees with the report by the International Rice Research Institute (IRRI, 2010) which reported that the average rice brown yield was 72 % at 14 % moisture content. It is also contrary to the report by Ayamdoo (2013) who investigated on different rice varieties and reported that the average brown rice yield from those varieties was 95 % at 14 % moisture content. This variation in rice brown yield from these reports could probably be due to different sites from which the crops were grown. Another possible reason is that because different cultivars were used, different results would be expected due to their different genetic characteristics.

5.2 Moisture and variety effects on white rice yield

White rice is a measure of the weight of bran removed from the brown rice kernel.



The outcome of this investigation showed that there were significant differences among all the three varieties at all the moisture contents (14 %, 12% and 10 %), (Figure 2), for white rice yield. Generally, better white rice yield was achieved at the 10 % moisture content. As far as white rice yield is concerned, it is advisable to mill at 10 % moisture content for Nabogu and Digang rice varieties. This disagrees with the report by the International Rice Research Institute (IRRI, 2010) which reported that paddy is often milled at 14 % moisture content for more white rice yield, even though this is dependent on the type of variety. At all the moisture contents, Nabogu rice variety had the highest white rice yield. This suggests that Nabogu rice variety has lighter bran layer than that of Gbewaa and Digang rice varieties making it possible to produce more white rice yield. It could therefore be concluded relative to this work that Nabogu rice variety may be milled at all the moisture contents in order to obtain maximum white rice yield.

5.3 Moisture and variety effects on broken grain yield

Broken rice grain is a percentage of broken grain obtained from the milled rice. Paddy moisture content affects rice breakage during the milling process. Rice breakage rapidly increases with the decreasing moisture content of the paddy (Peuty *et al.*, 1994). Rice with lesser broken grains is preferred both locally and internationally (Guisse, 2010). The results obtained from this study showed that broken grain yields of the three varieties used were highly influenced by moisture content (Figure 3). Yields were significantly different at all the moisture contents among all the three varieties. More grain breakages were at the 10 % moisture content in all the three varieties, with Digang rice variety having the highest grain breakage. This suggests that rice grain breakage increases with a decreasing moisture content of the paddy as conformed to Peuty *et al.* (1994) who reported that rice breakage rapidly increases with the decreasing moisture content of



the paddy. Lesser grain breakages were at the 14 % moisture content in all the three varieties, with Nabogu rice variety having the lowest grain breakage. Based on the results of this investigation coupled with other previous findings highlighted here, it would be proper to suggest that these rice varieties should be milled at 14 % moisture content of the paddy in order to obtain lesser grain breakage. The probable reason for Digang rice variety recording the highest grain breakage at all the moisture contents (14 %, 12 % and 10 %) could be that it is genetically complex and needs to be experimented using a wider range of moisture content levels in order to determine a suitable moisture content level for its milling, since “broken grains” count greatly as far as marketing and consumption of rice both locally and internationally are concerned. The results also showed that Nabogu rice variety is a good variety because it recorded the lowest grain breakages at all the moisture contents and it is likely to be accepted by consumers. Its average percentage yield of broken rice grain at the 14 % moisture content was 9.51 % which disagreed with the report of Ayamdoo (2013) who investigated on different rice varieties and reported that the average broken rice grain yield was 12 %.

Rice grades in the market contain between 5-25 % broken kernels (IRRI, 2010). Guisse (2010) reported that in the Japanese inspection standard for complete milled rice, the upper limits of broken grains to be included to the first, second and off-grade rice classes are 5 %, 10 % and 15 % respectively. On the other hand, in the United States of America, the upper limits are 4 %, 7 %, 15 % and 25 % for the first, second, third and fourth grade rice respectively.

In this work, the least broken grains were achieved at the 14 % moisture content. Averagely, they were 15.9 %, 9.5 % and 22.89 % in Gbewaa rice, Nabogu rice and Digang rice respectively.



Nabogu rice and Gbewaa rice varieties fall within the second grade category whilst Digang rice is close to the fourth grade category.

5.4 Moisture and variety effects on head rice yield

Head grain normally includes broken grains that are 75-80 % of the whole kernel. Head rice yield is the weight of head grain obtained from the paddy sample.

Unbroken rice grains (head rice) are mostly demanded both at the international and the local markets (Guisse, 2010). Head rice yield could be used to judge or could be a measure of the nutritive value of recovered milled rice to some extent. This is because good head rice yield means only the husks were removed without taking bits of germ or embryo where the nutrients are concentrated (Ayamdoo, 2013). The Global Food Security Response (GFSR, 2009) reported that imported rice with higher percentage of head rice grain (low percentage broken) sells for US \$ 650/mt. The outcome of the investigation as shown in Figure 4 is that higher head rice yield was recorded at the 14 % moisture content in all the three rice varieties. This suggests that in order to achieve higher head rice yield, milling should be done at 14 % moisture content for all the three rice varieties. Nabogu rice variety recorded the highest head grain at all the moisture contents, followed by Gbewaa rice variety. At the 14 % moisture content, the average percentage head rice yields were 55.47 %, 62.0% and 47.11 % for Gbewaa rice, Nabogu rice and Digang rice varieties respectively. This finding is closely related to the report by Thompson *et al.* (1990) who reported that maximum head rice yield ranges from 55 % to 65 %. It could also be suggested based on the results that for a good head yielding variety, Nabogu rice variety should be promoted.



5.5 Moisture and variety effects on rice bran yield

Rice bran yield is the weight of bran obtained from the brown rice kernel.

It was shown in Figure 5 that higher rice bran yields were recorded at the 12 % moisture content in all the three rice varieties, with Digang rice variety recording the highest rice bran yield. The probable reason might be that Digang rice has a thicker bran layer than that of Gbewaa and Nabogu rice varieties. Belsnio (1980) and IRRI (2010) both reported that in the milling process, the smaller the percentage of bran removed from the milled rice (brown rice), the higher the milling degree. Milling degree is a measure of the weight of bran removed from the brown rice kernel. This suggests that for more rice bran yield, milling should be done at the 10 % and the 14 % moisture contents but not at the 12 % moisture content. At the 14 % moisture content, the average percentage bran yields were 5.93 %, 6.23 % and 6.43 % and at the 10 % moisture content, they were 8.11 %, 4.76 % and 4.43 % in Gbewaa, Nabogu and Digang rice varieties respectively. This disagreed with the report of IRRI (2010) ,which reported that the average rice bran yield ranged between 8 % and 12 %; and also disagreed with the report of Guisse (2010), who reported that the average percentage rice bran yield was 13.5 %. This variation in rice bran yield between this research and that of Guisse's and IRRI's could probably be due to different cultivars or different milling machines used.

5.6 Moisture and variety effects on rice husk yield

Rice husk yield is the weight of husks obtained from a sample of paddy.

Rice husk is one of the components that determine the milling yield of rice. Milling yield is the weight of milled rice (brown rice) obtained from a sample of paddy. The more the husk, the lesser the milling yield and vice versa. The results from Figure 6 showed that Gbewaa rice



variety had the highest husk yield and Digang rice variety recorded the lowest (at the 12 % moisture content). Invariably, Gbewaa rice variety had the lowest milling yield and Digang rice variety recorded the highest milling yield, at the 12 % moisture content; since the husk component determines the milling yield (Figure 1). At the 14 % moisture content, Digang rice variety had the highest husk yield (Figure 6) and its correspondent brown rice yield was the lowest (Figure 1). At the 12 % moisture content the average percentage husk yields were 24.8 %, 22.8 % and 21.7 % whilst at the 10 % moisture content, they were 24.19 %, 16.81 % and 21.86 % in Gbewaa rice, Nabogu rice and Digang rice varieties respectively. At the 14 % moisture content, the average percentage rice husk yields were 22.7 %, 22.3 % and 23.6 % respectively for Gbewaa rice, Nabogu rice and Digang rice varieties. This finding disagreed with the reports of Li (2003), Guisse (2010) and IRRI (2010) where they revealed that the average percentage rice husk yields were 17.13 %, 20 % and 20 % respectively. The probable reason for the variation in rice husk yield in this study and that of those researchers mentioned above could be that different milling machines and different rice varieties were used. Quite apart from this, the differences that existed in rice husk yield among the three rice varieties in this study could be that Gbewaa rice variety which recorded the highest rice husk yield has a thicker husk layer than the other two rice varieties.



CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions arrived at, and the recommendations derived from the conclusions made.

6.1 Conclusions

This study revealed that maximum head rice yields with the least broken grains were achieved when paddy was milled at 14 % moisture content. The highest white rice yields, bran yields and brown rice yields were achieved at the 10 % moisture content. On the other hand, the highest broken grains with the least head rice yields were achieved when paddy was milled at 10 % moisture content. It could be concluded based on the results that for a good head yielding variety, Nabogu rice variety should be promoted and milling done at 14 % moisture content.

6.2 Recommendations

From the results and conclusions made it is recommended that:

- This research should be repeated using other local varieties to generate more information on the quality of local rice.
- Similar work should be carried out with paddy being milled straight and not parboiled for more information also.
- The nutritional aspects of these rice varieties should be investigated (when milled at 14% moisture content).



REFERENCES

Amanor-Boadu, V. (2012). Rice price trends in Ghana (2006-2011). Department of Agricultural Economics, Kansas State University. METSS-Ghana Research and Issue Paper Series No. 02-2012-June 2012

Apori-Buabeng, F. (2009). Market Organisation and Consumers' Perception of Locally Produced Rice in the Ashanti Region of Ghana. An M.sc.Thesis submitted to The School of Graduate Studies, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. pp.75-77.

Ayamdoo, J. A. (2013). Evaluating the Effects of Parboiling Process on the Physico-Chemical Properties of Rice (*Oryza sativa* L). M. Phil.Thesis Submitted to the Department of Biotechnology, Faculty of Agriculture, University For Development Studies. Pp:2-3.

Balasubramaniyan, P. and Palaniniappan, S. P. (2001). Principles and Practices of Agronomy: Integrated Farming Systems. Agrobios (India) pp. 562.

Basorun, J. O. (2003). Analysis of the Relationships of Factors Affection Rice Consumption in a Targeted Region in Ekiti-State, Nigeria. *Journal of Applied Quantitative Methods*, 4(2): 145-153.

Belsnio, B. (1980). The Anatomy and Physical Properties of Rice Grain. Towards integrated community and Pest Management in Grain Storage. FAO, Rome.

Berisavljevic, G. K., Blench, R. M., and Chapman, R. (2003). Some Features of Rice Production in Ghana. Available on line at <http://www.odi.org/resources/download/3159.pdf>. Accessed 09/24/09.



Bimpong, I. K. (1998). Rice Cultivation in Ghana. Daily Graphic 24th November, 1998, p.7

Boumas, G. (1985). Rice In: Grain Handling and Storage. Elsevier Science Publishers B. V., Pp 9-10.

CARD (2010). Mapping of Poverty Reduction Strategy Papers (PRSPs), Sector Strategies and Policies related to rice development in Ghana. [<http://www.ijessnet.com/wp-content/uploads/2014/09/13pdf>] (Accessed: 05/02/14).

Champagne, E. T., Marshall W. E. and Goynes, W. R. (1990). Effects of degree of milling and lipid removal on starch gelatinization in the brown rice kernel. *Cereal Chem* 67: 570-574.

Champagne, E. T., Bett, K. L., Vinyard, B. T., Wedd, B. D., McClung, A. M., Barton, F. E., Chipili, J., Sreenivasprasad, S., Nutsugah, S. K., Twumasi, J. K. and Dartey, K. (2003). Rice blast management in Ghana: Characterization of the pathogen diversity. *J. Ghana Sci. Assoc*; 5: 20-25.

Cnossen, A. G., Jimenez, M. J. and Siebenmorgen, T. J. (2003). Rice fissuring response to high drying and tempering temperatures. *J Food Eng* 59: 61-69.

CSIR-SARI (2010). CSIR-SARI released high yielding varieties. Annual report.[csirsavannah.blogspot.com/] (Accessed: 05/02/14).

Duke, J. A. and Ayensu, E. S. (1985). Medicinal Plants of China. Reference Publications. Inc. Aglonac, MI.

F.A.O (2004). International Year of Rice: Rice based production systems and their associated postharvest operations. [<http://www.fao.org/rice2004/en/rice-us.htm>] [Accessed 26th May, 2010]



FAOSTAT (2012) in **MAFAB** (2013). Analysis of Incentives and Disincentives for rice in Ghana. Food and Agriculture Organisation of the United Nations. Supported by the Bill and Melinda Gates Foundation. pp. 4-15.

GFSR (2009). Global Food Security Response, Ghana Rice Study micro-report #156.[GFSR_Ghana_Rice_VC_analysis.pdf] (accessed 05/02/14).

GSSP (2013). Patterns of Adoption of Improved Rice Technologies in Ghana. IFPRI Working Paper 35/July, 2013. pp. 10

Guessi, R. (2010). Post Harvest Losses of Rice (*Oryza spp*) From Harvesting to Milling. A Case Study in Besease and Nobewan in the Ejisu Juabeng District in the Ashanti Region of Ghana. An M. Sc. Thesis submitted to the Board of Post Graduate Studies Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. pp. 15-36.

Hartwell, J. L. (1967). Plants Used against Cancer. A survey. *Lloydia* 30:379-436

Horna, J.D., Smale, M. and von Oppen, M. (2005). Farmers Willingness to Pay for Seed-Related Information: Rice Varieties in Nigeria and Benin. International Food Policy Research Institute. Washington D. C, U.S.A.

Iguaz, A., Rodriguez, M. and Virseda, P. (2006). Influence of handling and processing of rough rice on fissures and head rice yields. *J Food Eng.* 77: 803-809.

IRRI (2010). Rice Policy- World Rice Statistics (WRS). [<http://www.irri.org/science/ricestat>] [Accessed 3RD March, 2014]

Juliano, B. O. (1993). Rice in Human Nutrition. Available at <http://www.fao.org/inpho/content/documents/vlibrary/.../T0567E00.htm>. Accessed 10/05/09.



Li, Y. B., Cao, C. W., Yu, Q. L. and Zhong, Q. X. (1999). Study of rice fissuring during intermittent drying. *Dry Tech.* 17(9): 1779-1793.

Li, J. (2003). The Natural History of Rice. [www.encyclopedia.com/topic/rice.aspx] (Accessed: 05/02/14).

Linares, O. F. (2002). The History and Future of African Rice. [www.jstor.org/stable40175114] [Accessed May 26th 2010]

Linscombe, L. S. (2006). Rice Cultivar Designated Cheniere. Available at <http://www.freepatentsonline.com/741725.htm>. (Accessed: 03/03/10).

Lloyd, B. J. and Siebenmorgen, T. J. (1999). Environmental conditions causing milled rice kernel breakage in medium-grain varieties. *Cereal Chem.* 76:426-427.

MOFA (2007). Food and Agricultural Sector Development Plan (FASDEP II). [http://www.grain.org] [Accessed: 16th April, 2015]

MOFA (2009). Agriculture in Ghana: Facts and Figures. Statistics, Research and Information Directorate (SRID). Ministry of Food and Agriculture, Accra.

MOFA (2009). Evaluation of the Ghana Rice Campaign. [http://sciencedomain.org/download/NjgyNkBACGY] (Accessed: 05/02/14).

MOFA (2015). Mofa Opens up Useful Information to Ghanaians. [webmaster@mofa.gov.gh] [Accessed: 6th November, 2015].

MOFA (2009). National Rice Development Strategy, Accra, Ghana. Introduction of Strategy Development Partners in Ghana, 23rd April 2009. [www.jica.go.jp/activities/issues/agricul/pdf] [Accessed: 10th May 2010]



MOFA (2010). Agriculture in Ghana: Facts and Figures. Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture, Accra.

MOFA and JICA (2008). The Study on the Promotion of Domestic Rice in the Republic of Ghana. [https://www.microlinks.org/sites/microlinks/files/resource/files/GFSR_Ghana] [Accessed: 16th April, 2015].

Monsoor, M. A., Proctor, A. and Siebenmorgen, T. J. (2004). Surface lipid and free fatty acids (FFA) content of head and broken rice produced by milling after different drying treatments. *Cereal Chem.* 81:705-709.

Monsoor, M. A. and Proctor, A. (2003). Relative FFA formation and lipid oxidation of commercially milled un separated, head and broken rice. *J. Am. Oil Chem. Soc.* 80:1183-1186.

Ntanos, D. Philippou, N. and Hadjisavva-Zinoviadi, S. (1996). Effect of rice harvest time on milling yield and grain breakage. *Cahiers Options Méditerranéennes*. 15(1), 23-28.

Nwanze, K. F., Mohaptra, S., Kormawa, P., Shallemiah, K. and Bruce-Oliver, S. (2006) Building the capacity for farmer based organisation for sustainable rice farming in northern Ghana. *Journal of the Science of Food and Agriculture*. 86:675-677.

Nyanteng, V. K. (1987). Rice in West Africa. Consumption, Imports and Production with Projection to the year 2000. Monrovia, Liberia, WARDA. [goliath.ecnext.com/coms2/./The-fortunes-and-misfortunes-of.htm] [Accessed 16th May 2010]

ODI (2003). Rice production and Livelihood in Ghana. [www.odi.org/resources/docs/3984.pdf] (Accessed: 05/02/14).



Oyedele O.A. and Adeoti O. (2013). Investigation in to optimum moisture content and parboiling Time for Milling Igbemo Rice. *J Rice Res.* 1: 101.doi: 10. 4172/jrr.1000101

Peuty, M. A., Themelin, A., Bonazzi, C., Amaud, G., Salakhe, V. M. and Singh, G. (1994).Paddy drying quality improvement by process optimization.In Proceedings of the Agricultural Engineering Conference Bangkok, Thailand. 7-10th December, 1994.

Proctor, D. L. (2010). Post harvest losses (Grains); Grains storage techniques. [en.wikipedia.org/wiki/postharvest_losses-grains]

Reed, C. F. (1976). Information summaries on 1000 economic plants. *Plant Molecular Biology* 35:69-77.

Riceland International (2011). Parboiled Rice.[<http://www.ricelandgroup.com/parboiling.html>].(Accessed: 16th April,2015).

Rose, M. G. M., Monica, R.de la B., Rene, C. C. and Jemaime, A. C. (2009). Characteristics of Anatomical, Chemical and Biodegradable Properties of fibres from corn, wheat and rice residues.*Chilean Journal of Agricultural Research*69 (3): 406-415.

Sanint, L. R., Correa, V. F. J. and Izquierdo, J. (1998). Current situations and Issues on rice production in Latin America and the Carribean. Paper presented on the 19th meeting of the IRC,FAO,Rome, Italy.[<http://www.fao.org/docrep/008/y5682e0e.htm>] [Accessed 10th April 2010]



Siebenmorgen, T. J., Perdon, A. A., Chen, X. and Mauromoustakos, A. (1998). Relating rice milling quality changes during adsorption to individual kernel moisture content distribution. *Cereal Chem.* 75:129-136.

Siebenmorgen, T. J. and Jindal, V. K. (1986). Effects of moisture adsorption on the head rice yields of long-grain rough rice. *Trans. ASAE.* 29:1767-1771.

Siebenmorgen, T. J. and Qin, G. (2005) Relating rice kernel breaking force distributions to milling quality. *Trans ASAE.* 48: 223-228.

Sivasankar, B. (2010). Food Processing and Preservation. PHI Learning private Limited, M-97. Connaught Circus, New Delhi-110001.p. 284.

Takoradi, A. A. (2008). Ghana needs 700,000 metric tonnes of rice annually. Available at <http://www.modernghana.com/news/185343/1/ghana-needs-700000-tonnes-of-rice-annually-but-cur.htm>. (Accessed, 16th April, 2015).

Thakur, A. K. and Gupta, A. K. (2006). Two stage drying of high moisture paddy with intervening rest period. *Energy Conversion and Management* **47**: 3069-3083.

Thompson, J. F., Knutson, J. and Jentins, B. (1990). Analysis of Variability of Rice Milling Appraisals., *Applied Engineering in Agriculture.* 6(2) Pp: 194-198.

Tokpa, E. S. (2010). Seed and Grain Quality Characteristics of Some Rice Varieties in Ghana. An M.sc. Thesis submitted to The Department of Horticulture, Faculty of Agriculture and Natural Resources of The Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. pp. 31-64.



Troare, K. (2005). Characterization of Novel Rice Germplasm from West Africa and Genetic Marker Association with Rice Cooking Quality, Texas, USA: Texas A and M University, PhD thesis.

UNCTAD (2010). Rice Characteristics. Information Communication Market Information in the Commodities Area.[www.unctad.org/en/docs/ecn162010d4enpdf][Accessed 30th April 2010]

Unnevehr, L. J. (1986). Consumer Demand for Rice Grain Quality and Returns to Research for Quality Improvement in South East Asia.*American Journal of Agricultural Economics*. 68 (3): 634-641.

USAID (2009).The Global Food Security Response West Africa Rice Value Chain Analysis: Ghana Rice Study. Micro-report, USDA, 2011 Grain and Feed Annual Report.[usaid.gov/pdf_docs/pnaea873.pdf].(Accessed, 16th April, 2015).

USDA (1990). Inspection handbook for the sampling, inspection, grading, and certification of rice. H.B.918-11. USDA Agricultural Marketing Service: Washington, DC.

USDA (2008). Rebuilding Agriculture and Food Security in Afganistan. Foreign Agricultural Services. [<http://www.fas.usda.gov/ICD/afganistanasp>][Accessed 20th January 2010].

Veena, H. and Latharani T. R. (2014). An Efficient Method of Classification of Rice Grains using Morphological process. *International Journal of Innovative Research in Advance Engineering*. 1 (1): P. 218.

Wang, Y. J., Wang, L., Shephard, D., Wang, F. and Patindol, J. (2002). Properties and structures of flours and starches from whole, broken, and yellowed rice kernels in a model study. *Cereal Chem*. 79:383-386.



WARDA (2005). Rice, a strategic crop for Food Security and Poverty Alleviation. [www2.slu.se/cigar/CGIAR_WARDAppt] [Accessed May 26th 2010].

WARDA (2008). Annual Report. Cotonou, Benin [www.warda.org/warda/impactpub][Accessed 24th March 2010]

WFP (2010). Analysis of Incentives and Disincentives for rice in Ghana. Food and Agriculture Organisation of the United Nations. Supported by the Bill and Melinda Gates Foundation. pp. 4-15.

Winrock International (2009). Analysis of Incentives and Disincentives for rice in Ghana. Food and Agriculture Organisation of the United Nations. Supported by the Bill and Melinda Gates Foundation. pp 4-15.

Yadav, B. K. and Jindal, V.K. (2008). Changes in head rice yield and whiteness during milling of rough rice (*Oriza sativa L.*). *J Food Eng.* 86: 113-121.



APPENDICES

APPENDIX A

A 1. Analysis of variance for rice brown yield (g)

Source	DF	SS	MS	F	P.value
Variety	2	437.35	218.67	112.76	0.000
MC	2	68.60	34.30	17.69	0.000
Variety*MC	4	412.29	103.07	53.15	0.000
Error	18	34.91	1.94		
Total	26	953.15			

A 2. Analysis of variance for white rice yield (g)

Source	DF	SS	MS	F	P.value
Variety	2	1327.37	663.69	40.07	0.000
MC	2	1010.23	505.17	30.50	0.000
Variety*MC	4	1120.92	280.23	16.92	0.000
Error	18	298.17	16.57		
Total	26	3756.80			



A 3. Analysis of variance for head rice yield (g)

Source	DF	SS	MS	F	P.value
Variety	2	32744.7	16372.3	399.96	0.000
MC	2	15006.7	7503.4	183.30	0.000
Variety*MC	4	5610.9	1402.7	34.27	0.000
Error	18	736.8	40.9		
Total	26	54099.2			

A 4. Analysis of variance for broken grain yield (g)

Source	DF	SS	MS	F	P.value
Variety	2	25406.6	12703.3	302.41	0.000
MC	2	14650.4	7325.2	174.38	0.000
Variety*MC	4	1537.2	384.3	9.15	0.000
Error	18	756.1	42.0		
Total	26	42350.3			



A 5. Analysis of variance for rice husk yield (g)

Source	DF	SS	MS	F	P.value
Variety	2	437.35	218.67	112.76	0.000
MC	2	68.60	34.30	17.69	0.000
Variety*MC	4	412.29	103.07	53.15	0.000
Error	18	34.91	1.94		
Total	26	953.15			

A 6. Analysis of variance for rice bran yield (g)

Source	DF	SS	MS	F	P.value
Variety	2	200.36	100.18	9.80	0.001
MC	2	628.51	314.25	30.75	0.000
Variety*MC	4	687.02	171.75	16.81	0.000
Error	18	183.93	10.22		
Total	26	1699.82			



Appendix B: Plates



Plate 1: Rice varieties used



Plate 2: paddy samples in drying trays





Plate 3: Experimental machine used to mill the rice samples



Plate 4: Grading machine



Plate 5: Rice polishing machine



Plate 6: Moisture meter

