POST HARVEST LOSSES OF RICE (*Oriza spp*) FROM HARVESTING TO MILLING: A CASE STUDY IN BESEASE AND NOBEWAM IN THE EJISU JUABENG DISTRICT IN THE ASHANTI REGION OF GHANA.

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BY

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DECLARATION

I hereby declare that this thesis, except for references to other peoples work which have been duly acknowledged, (submitted to the Board of Postgraduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana) is the result of my own research work and investigation and has not been presented for any other degree anywhere else before.

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ABSTRACT

Rice (*Oriza sativa*) is the most important staple food in the world, feeding almost half of the world's population. Sub Saharan Africa rice imports accounts for more than 30% of the world's imports even though it grows a lot of rice. Rice production notwithstanding, there are lots of post harvest losses of rice, these losses have however not been estimated for effective control. This study therefore aimed at estimating post harvest losses of rice from harvesting to milling and suggests critical areas of control.

The study was carried out at "Besease" and "Nobewam" in the Ejisu Juabeng District of the Ashanti Region of Ghana to assess rice farmers perception and knowledge of post harvest losses in rice and to estimate post harvest losses that occur from harvesting to milling.

The results of the survey showed that postharvest losses of rice were considered too high by 90% of the respondents (rice farmers) and that they needed interventions to reduce the losses.

The study showed that harvesting losses were higher (2.93%) when sickle harvesting method was used than when panicle harvesting method which resulted in 1.39% was used. Threshing losses were also higher (6.14%) when threshing was done using the "bambam" (a big locally made wooden box) than when the bag beating method (2.45%) was used. Harvesting losses ranged between 4.07% and 12.05% at farmer's fields. Storage losses were 7.02% while drying losses were 1.66%. SB 30 milling machine was more efficient producing 67.3% head grains compared to SB 10 (50%) and the locally manufactured machine (47.3%). Post harvest losses from harvesting, threshing, drying, and storage were found to range from 11.10% to 27.14% with an average of 19.12%. SB 30 though more efficient than SB 10 and the local machine, does not

produce competitive percentage head grains. Milling machines that produce higher percentage head grains has to be introduced to make local rice milling more economically competitive.

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DEDICATION

This thesis is dedicated to the memory of the late SHERIFF EBRIMA B. CONTEH who met up with his untimely death on October 22nd 2005 as a victim of the plane crash (Bellview Airlines Flight 210, a Boeing 737 -200 that crashed in Nigeria and killed all the 117 people on board). May his gentle soul along with all the other victims rest in Perfect Peace, Amen.

Sheriff has created a vacuum in my life that can never be filled.

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LIST OF ACRONYMS

ACIAR -Australian Center for International Agricultural Research.

Africa Rice - Africa Rice center

ASEAN- Association of South East Asian Nations

CGIAR-Consultative Group on International Agricultural Research

CIRAD-Agricultural Research for Development

EC- European Commission

FAO- Food and Agricultural Organization

HYV- High Yielding Variety

IDRC- International development Research Center

IFPRI-International Food Policy Research Institute

IRRI- International Rice Research Institute

LRAN- Land Research Action Network

MoFA- Ministry of Food and Agriculture

NAPHIRE- National Post Harvest Institute for Research and Extension

NARP- National Agricultural Research Project

NRI- National Resources Institute

NFA- National Food Authority

SSA- Sub Saharan Africa

STRASA- Stress Tolerant Rice for Africa and South Asia

UNCTAD- United Nations Conference on Trade and Development

USAID- United States Agency for International Development

WARDA- West Africa Rice Development Agency

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Rice (*Oriza spp*) is after wheat, the most widely cultivated cereal in the world and it is the most important food crop for almost half of the world's population (IRRI, 2009). The African rice (*Oriza glaberrima*) is thought to have originated in the Central Delta of the Niger River where it may have been grown since 1,500BC. However, its domestication was around 3000BC in West Africa and the Asian rice species were introduced in West Africa by the Portuguese around 1500BC. The upper coastal part of West Africa was historically known as the "Rice Coast" due to its abundance in the region (Diange, 2008).

It is estimated that rice sustains the livelihood of 100 million people and its production has employed more than 20 million farmers in Africa (WARDA, 2005). Sub Saharan Africa accounts for more than 30% of the worlds rice import with an import bill of more than US$ 2 billion per year, the reasons for that being urbanization and population growth (FAO, 2008).

Rice consumption in West Africa has been steadily growing at an annual rate of 6% since 1973, with most of this growth caused by substitution for traditional coarse grains, roots and tubers. Rice is providing more than one third of cereal calorie intake in West Africa in general, and up to 85% in traditional rice consuming countries like

Senegal, Guinea-Bissau, Guinea, Sierra Leone, Liberia La Côte d'Ivoire and The Gambia. The Food and Agriculture Organization (1990) projected that the annual growth in the West African rice consumption would remain high, at 4.5%, through the year 2000 and beyond.

Rice is the most important staple food crop in The Gambia with a per-capita consumption rate of approximately 117 kg. This is top amongst Sahelian countries and the third highest in West Africa (WARDA, 1996). It is cultivated as a sole crop in all ecologies especially in the lowlands and accounts for 25 to 30% of total cereal consumption. The Gambia's annual total rice requirement is estimated at 157,616 metric tons, and in 2003 only 12% is being met through local production (19,000 metric tons). This huge deficit is met through costly imports, which in the year 2000 cost The Gambia D196 million for 94 metric tons of rice (Gambia Statistical Department, 2003). Post harvest losses that occur during local rice production if reduced could reduce the huge deficit.

Post harvest losses of rice can be quantitative or qualitative. Quantitative losses lead to a reduction in weight or volume of the final usable product from the potential yield or harvestable paddy while qualitative losses leads to a reduction in value of usable product due to physical and chemical changes in the rice which diminish the grain size, cause poor appearance, bad taste and foul aroma.

1.2 Problem Statement

The high and rising population growth rate in Africa has led to the high demand for rice in Sub Saharan Africa and its consumption is growing faster than that of any other staple food in Africa (WARDA, 2008). Between 2005 and 2008, the price of milled rice increased four folds from US$250 to almost US$1000 per metric tonne. Four out of the eleven largest rice importing countries in the world are within Sub Saharan Africa with Nigeria as the world's largest importer (WARDA, 2007). In

2003, Ghana imported 415,150 tonnes representing 60% of the country's total rice consumption (LRAN, 2008). The Gambia also imports 175,000 tonnes annually representing 70% of total rice consumption (WOW, 2008).

Strategies to reduce dependency on importation include decreased consumption which is not a viable option, increasing tariffs on imported rice increasing the area under current cultivation, increasing productivity and proper post harvest practices to minimize loss and improve quality.

When 20 percent of a harvest is lost, the actual crop loss is just part of the problem. Also wasted are 20 percent of all the factors that contributed to producing the crop: 20 percent of the land used to grow the food and 20 percent of the water used to irrigate it, along with the human labor, seeds, fertilizer, and everything else. In other words, postharvest food loss translates not just into human hunger and financial loss to farmers but into tremendous environmental waste as well (Earthtrend, 2001).

1.3 Justification

The International Rice Research Institute (IRRI) in 1995 made a projection indicating a world rice need of 758 million tons in the year 2025, which was 70% of more rice than was consumed in 1995. The Food and Agriculture Organization in 1982 reported that post harvest losses of food in Africa alone accounts for 40-60% of production and it is the areas of main concern in the developing countries of the world.

Post harvest losses present one of the main problems in all grain production including rice. Losses in rice can occur during any of the various post harvest stages like harvesting, threshing, drying, storing, transportation, winnowing and milling.

According to Panhwar (2006), reduction of post harvest losses reduces cost of production, trade distribution and lowers the prices for consumers at the same time increasing the farmer's income.

However, there is insufficient information on post harvest losses of rice produced locally. The unavailability of sufficient information on precise post harvest losses and the nature of the losses make it difficult to estimate post harvest losses and determine where most of the losses occur along the production chain and how to address them.

1.4 Objectives

The main objective of the research therefore is to determine the post harvest losses of rice from harvesting to milling and indicate potential solutions to them.

The specific objectives of the research were:

1. To determine rice farmers perception and knowledge about post harvest losses of rice.
2. To measure the extent of post harvest losses of rice at harvesting, threshing, drying, storage and milling.
3. To determine losses associated with the use of different types of milling machines; SB 10, SB 30 and a locally manufactured milling machine in Ghana.
4. To determine the influence of three different millers using the same mill on the milling yield of rice.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Brief Description of Rice

Rice (Oryza spp) belongs to the family *Graminae*. It is a cereal grain grown in hot countries providing seeds that are used as food. Rice refers to two grass species (*Oryza sativa* and *Oryza glaberrima*) and is native to tropical and subtropical southeastern Asia and to Africa. The plant measures 2-6 feet tall and has long, flat, pointy leaves and stalk-bearing flowers which produce the grain known as rice. 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 rich in genetic diversity, with thousands of varieties grown throughout the world (IRRI, 2009).

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).

There are many unproven mythological tales as to how rice came to be, though historians hold little or no stock in any. Most believe that the roots of rice come from 3000 BC India, where natives discovered the plant growing in the wild and began to experiment with it. Cultivation and cooking methods are thought to have spread to the West rapidly and by medieval times, Southern Europe saw the introduction of rice as a hearty grain (http//www.ricehistory.html).

It is also believed that rice cultivation began simultaneously in many countries over 6500 years ago. The first crops were observed in China (Hemu Du region) around 5000 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, 2010a)

The first cultivators of rice in America 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 tons of rice a 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 a crop (USDA, 2008).

The African species of rice (*Oryza glaberrima*) was cultivated long before Europeans arrived on the continent. At present, *O. glaberrimais* 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).

Between 1500 and 800 B.C., the African species (*Oryza glaberrima*) spread from its original center, the Delta of Niger River, and extended to Senegal. However, it never developed far from its original region. Its cultivation even declined in favor of the Asian species, possibly brought to the African continent by the Arabians coming from the East Coast from the 7th to the 11th centuries.

2.3 Diversity Of Rice

Great diversity exists in rice because of its long history of cultivation and selection under diverse environments. Each environment offers different light, moisture, temperature and soil creating mutations and variations within each field (Hanks, 1972). Humans have managed to create through selection and adaptation about 120,000 varieties of rice around the world. The greatest species variations occur in Asia and Africa, in *Oryza sativa and Oryza glaberrima* respectively. (Khush, 1997).

2.4 Importance Of Rice

Rice is consumed by nearly one-half of the entire world population. It is a staple food especially in East, South East Asia, the Middle East and West Indies and it is becoming increasingly popular in Africa. Rice is one of the few foods in the world which is entirely non-allergenic and gluten-free (http://www.hungrymonster.com/foodfacts.cfm).

Throughout history rice has been one of man's most important foods. This unique grain helps sustain two-thirds of the world's population. Rice is life for thousands of millions of people. It is deeply embedded in the cultural heritage of societies. About four-fifths of the world's rice is produced by small-scale farmers and is consumed locally. Ninety five percent of the world's rice is grown by less developed countries, mostly in Asia (IRRI, 1995).

Rice cultivation is the principal activity and source of income for about 100 million households in Asia and Africa (Sanint *et al.*, 1998).

Rice is naturally fat, cholesterol and sodium free. 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 population. It is so important in Asia that it influenced local language and beliefs. In classical Chinese, the same term refers to both "rice" and "agriculture". In many official languages and local dialectics the verb "to eat" means "to eat rice". Indeed, the words "rice" and "food" are sometimes one and the same in eastern semantics (UNCTAD, 2010b).

Worldwide rice it is grown on 150 million hectares, more than 10% arable land. Total world production exceeds 500 million tones of paddy (Chang, 2004). Rice cultivation is the principal activity and 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 (IRRI, 2009).

Food security, which is the condition of having enough food to provide adequate nutrition for a healthy life, is a critical issue in the developing world. About 3 billion people, nearly half the world's population, depend on rice for survival. In Asia as a whole, much of the population consume rice in every meal. In many countries, rice accounts for more than 70% of human caloric intake. The percentage of total calorie intake contributed by rice varies widely between different regions. Just over 30% of all calories in Asia come from rice (http://www.patentlens.net>patentlens).

Beyond providing sustenance, rice plays an important cultural role in many countries.

Products of the rice plant are used for a number of different purposes, such as fuel, thatching, industrial starch, and art work (http://www.patentlens.net/daisy/Rice genome/3649.html).

The Asian varieties are high yielding varieties and are used for medicinal purposes as well as food. According to Hartwell (1967), the seeds of the rice plant are used in folk medicine for breast cancers, tumors, warts, and stomach indurations. The flowers are dried as cosmetic and dentifrice in China; awns are used for treatment of jaundice in China (Duke and Ayensu, 1984). The stem is used for bilious conditions; ash for discharges and wounds, sapraemia in Malaya; infusion of straw for dysentery, gout, 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. Rice water is used for fluxes and ulcers and applied externally for gout with pepper in Malaya. Boiled rice is used for carbuncles in Malaya and poultice onto purulent tumors in the East Indies. The root is considered astringent, anhidrotic, and is decocted for anemia. Sprouts are used for poor appetite, dyspepsia, fullness of abdomen and chest, and weak spleen and stomach in China. The lye of charred stems (merang, Indonesia) is used as a hair wash and used internally as an abortifacient. In the Philippine Islands, an extract (tikitiki), rich in anti neurotic B_1 vitamin, made of rice polishing, is used in treatment of infantile beriberi and for malnutrition in adults (Reed, 1976). Because of its importance in food security, income generation and political stability, the Food and Agricultural Organization (FAO) declared the year 2004 as the international year of rice (FAO, 2004).

2.4.1 Rice Production Around the World

Today, rice is grown and harvested on every continent except the Antarctica, where conditions make its growth impossible. The majority of all rice produced comes from India, China, Japan, Indonesia, Thailand, Burma, and Bangladesh. Asian farmers still account for 92% of the world's total rice production. More than 550 million tons of rice is produced annually around the globe (Rose *et al*., 2009).

2.4.2 Rice Production, Importation and Consumption in Sub Saharan Africa

African rice consumption exceeds its production level. Only 54% of Sub Saharan Africa rice consumption is supplied locally (Ininda, 2008). Rice could be considered a region-wide strategic commodity in West Africa because among all agricultural commodities, rice "shows the highest potential for growth and could subsequently generate the largest producer benefits downwards among many countries and for the region as a whole (IFPRI, 2006).

Rice is the number one staple food in Ghana (Chipili *et. al*., 2003). Ghana experienced a rapid dietary shift to rice, particularly in the urban centers starting from early post-independence period. The trend was attributed to increased income, favorable government pricing policies, of rice and ease of cooking (Nyanteng, 1987). Per capita rice consumption increased from 17.5Kg to 38 Kg between the years 19992008 and is estimated to get to 63 Kg by the year 2018 (MoFA, 2009). Ghana depends largely on imported rice to make up the deficit in rice supply. In Ghana, rice imports increased from 250,000 tons in 1998 to 415,150 tons in 2003 and in 2003, Ghana's rice consumption is estimated at 561,400 metric tons per year, rice produced locally currently stands at 107,900 metric tons leaving a gap of 453,500 metric tons which have to be imported (Kunateh, 2009). Domestic rice which has accounted for 43% of the domestic market captured only 29% of the domestic market in 2003. In all, 66% of rice producers recorded negative results (LRAN, 2008). There is also 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, increased consumption of food away from home, the convenience of cooking and the ease of storage of rice. Rice is the most rapidly growing food source in Sub Saharan Africa with consumption growing at 5% per annum since 1961 (Nwanze, *et al.,* 2006).

The above facts of the increasing importance of rice in the Sub Saharan African region has its consequences on the region as it is causing rice production in the region not to keep pace with its consumption, it is also widening the domestic deficit which is met by importation. The area accounts for more than 30% of world rice imports with an import bill of about US$2 billion per year. The Africa Rice Center has projected that by 2015, total Africa rice imports could reach up to 20 million tons 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).

2.5 Basic Post Harvest Practices of Rice

Post harvest management of rice include harvesting, threshing, drying, storage and milling the rice crop. Harvesting and threshing methods of rice vary widely from farmer to farmer and also from country to country. The levels of mechanization, from country to country also differ widely. The methods may either be manual, animal or mechanical operated (FAO, 2007).

2.5.1 Harvesting

The optimal stage to harvest a rice crop is when the grain moisture content is between 20-25% or when 80-85% of the grains are straw colored and the grains in the lower parts of the panicle are in the hard doe stage. This is about 30 days after flowering. If the crop is harvested too late, many grains are lost through shattering or drying out and are cracked during threshing. Cracked grains do not germinate and they also break during milling. If rice is harvested too early, there will also be many immature seed grains and this will reduce quality. Immature rice kernels are very slender and chalky and this results in excessive amounts of bran and broken grains during milling. The two harvesting methods that are mostly used in Ghana are Panicle and Sickle harvesting. Panicle harvesting provides less harvesting losses when compared to sickle harvesting even though sickle harvesting is much quicker and has the potential of saving time and labor cost.

2.5.2 Threshing

Threshing should occur immediately after harvesting as the longer the harvested panicles remain in a stack, the higher the chance of discoloration or yellowing and shattering too. There are also two threshing methods that are widely used in Ghana, the first one is locally referred to as the "BAMBAM" method, in this method, sickle harvested rice is beaten very hard against a big locally made wooden box so that the grains will be detached from the straw and collected inside the box. The other type of threshing method is known as the "BAG BEATING METHOD" in which the panicle harvested rice is put in a bag and big sticks are used to beat the rice so that the grains will be detached from the panicles.

2.5.3 Drying

The main reason why rice should be dried is if rice contains a lot of moisture, there is active respiration and its nutrients become exhausted, causing a deterioration of the rice. Moisture promotes the propagation of harmful insects and micro-organisms, which also cause rice to deteriorate. The germination rate of rice is lowered and toxins are produced by the growth of mold. Consequently, it is indispensable to reduce moisture in rice to prevent deterioration (Wimberly, 1983).

Rice grains should be dried to less than 14% moisture content as soon as possible after threshing. When seeds are to be stored for a longer period, they should be dried to 12% or less and preferably stored in a sealed container. Drying and tampering the grain a number of times or in stages during the drying process will maintain quality. This means drying the grain for a number of hours and allowing it to cool before drying it again. This process should be repeated at least a number of times until the grain reached 14% moisture content or less.

2.5.4 Winnowing

Threshed rice can contain all kinds of trash like chaff, straw, empty grains, foreign seeds as well as mineral materials such as earth stones etc. Seeds should be cleaned as soon as possible after harvesting prior to storage. The simple traditional cleaning method is winnowing, which uses the wind or a fan to remove the light elements from the grain. Mechanical winnowers that incorporate a fan and several superimposed reciprocating sieves or screens are also now in use in many countries including West

African Countries.

2.5.5 Storage

Rice in storage respire by expending nourishment, consuming oxygen and generating carbon dioxide, water vapor and heat. Unless appropriate measures are taken, therefore, the temperature and moisture content of rice in storage might increase. This condition is also ideal for insects and micro organisms such as mold, promoting their growth and having them generate even more moisture and heat. Stored rice with high moisture content tends to increase respiration, promoting heat generation by respiration which in turn causes secondary degeneration of rice (Wimberly, 1983).

If rice seeds are to be stored for extended periods, it must have less than 13-14% moisture, it must be protected from insects and rodents and it must also be protected from absorbing moisture either through rain or the surrounding atmosphere. Most grains including rice are traditionally stored in 40-50kg sacs which are made from jute or woven plastic. These bags should be stacked under a roof or a shed and must be periodically fumigated to control insects. Some farmers use granaries which are made from timber, mud, cement or large woven baskets and these also suffer from insect and rodent damage.

Sealed storage is an option that has a lot of potential in the tropical regions. If rice grains are dried up to 14% and stored in a sealed storage, it reduces the risk of insects and rodent damage and the grains will not absorb moisture from the atmosphere or be damaged by rain. Sealed storage comes in all shapes and sizes. They may range from a sealed 200-liter drum to the more complex and costly sealed plastic commercial storages. Most large commercial steel and concrete silos being used in Western countries can be sealed for fumigation purposes at the same time.

2.5.6 Milling

The objective of milling is to remove the husk and the bran layers to produce an edible white rice of high quality. Depending on the requirements of the customer, milled rice should have a minimum of broken grains or kernels, be well polished and free from impurities.

It is often said that milling is more of an art than a science. Using good quality paddy in a well maintained mill operated by a skilled miller produces high quality head rice. Poor quality paddy will always result in poor quality milled rice irrespective of the type of rice mill and the skill of the miller. Similarly, the use of good milling equipment and good quality paddy will ensure a high quality product.

Most paddy grains are made up of 20% rice hull or husk, 10% bran or meal and 70% starchy endosperm also referred to as total white rice. Total white rice contains both whole and broken grains . Whole grains or broken grains should at least be 40-50% of the total milled rice. The by products from rice milling are rice bran, husk and fine broken grains.

In Ghana, the commonest milling machine types in use are SB10, SB30 which are both products of the republic of China and the locally made milling machine (Engelberg). Milling in all the three machines is done by putting the paddy directly into the hopper for milling. The machines SB10 and SB30 separates the husk, bran from the milled rice whilst the locally manufactured machine only separates the milled rice and brings out the husk and the bran together.

2.6 Post Harvest Losses of Rice

Rice grain is lost at every step from harvesting operations to consumption. Post harvest or post production losses of rice occur both on farm and off farm levels. The term post harvest losses in rice production means any reduction in the amount of edible rice grain due to reduction of availability, edibility, wholesomeness or quality that prevents the rice grains from being consumed by people (Harris and Lindblad, 1978). The reduction in the moisture content of rice grain and the removal of inedible portions such as husk and bran in the process of milling are not considered as post harvest losses.

Time and money are required to cultivate food products, and unless the farmer is providing food only for his own household, he automatically becomes part of the market economy: he must sell his produce, he must recover his costs, and he must make a profit.

Estimates of the post-harvest losses of food grains in the developing world from mishandling, spoilage and pest infestation are put at 25%; this means that one-quarter of what is produced never reaches the consumer for whom it was grown, and the effort and money required to produce it are lost-forever. Estimates of production losses in developing countries are hard to judge (FAO, 1989).

Both quantitative and qualitative losses occur in crops between harvest and consumption. Qualitative losses, such as loss in edibility, nutritional quality, caloric value, and consumer acceptability of the products, are much more difficult to assess than quantitative losses.

A study by the International Rice Research Institute (IRRI, 2007) in the Philippines has estimated that between 5 to 16 percent of rice is lost in the harvest process, which includes harvesting, handling, threshing, and cleaning. During the postharvest period, another 5 to 21 percent disappears in drying, storage, milling, and processing. Total estimated losses, not counting later losses by retailers and consumers, run from 10 to 37 percent of all rice grown (De Padua,1978). The Food and Agriculture Organization (1997) reports similar estimates of rice loss in Southeast Asia.

Other recent scientific surveys place rice losses in China at 5 to 23 percent (not counting processing) (Yong and Algader 1997), and in Vietnam at 10 to 25 percent under typical conditions and 40 to 80 percent under more extreme conditions (Phan and Nguyen 1995).

A survey that was carried out in 13 member countries of the Africa Rice Center indicated that some major problems common to many countries are inappropriate harvesting and field handling methods which causes serious post harvest losses and the milling of low quality rice According to the Africa Rice Center (2007), harvest and post-harvest losses account for 15 to 50% of the market value of the initial production which equates to a value of $30 to $75 per ton. In 2004, post-harvest losses were estimated to be about 38,000 tons of milled rice equivalent, a value of $20 million per annum. This is not a profitable or sustainable way to farm. In developing countries, post-harvest losses destroy about 15 to 16 percent of the rice crop (FAO, 2004). Some stages in the rice post-harvest system are more critical than others, particularly in tropical and subtropical areas where rice is more vulnerable to damage and more likely to suffer qualitative and quantitative losses. Among these critical stages, drying and storage are especially important. Between 10-40% of the food that is grown never reaches the market or a consumer's plate because of insects and rodents that get into storage containers, losses during harvesting and processing, market demand for "perfect" unblemished produce, and other factors (Satin, 1997;

FAO, 1997)

To effectively minimize these losses, the following must be done:

1. Understand the biological and environmental factors involved in postharvest deterioration and

2. Use the appropriate postharvest technology procedures that will slow down deterioration and maintain quality and safety of the commodities.

2.6.1 Losses At Various Stages of Production

Addressing the problem of postharvest losses is complicated because losses occur in so many different ways including during harvesting, threshing, drying, storage and milling.

2.6.1.1 Harvest Losses

Harvesting generally refers to all operations carried out in the field which include cutting the rice stalk or reaping the panicles, either laying out the paddy-on-stalk or stacking it to dry, and bundling for transport. There is a positive relationship between the method of handling and the degree of loss as shown by various studies. Too much paddy handling create problems both in quality and quantity (NAPHIRE, 1997).

Several methods of harvesting have evolved during the progress of rice production. The most common among the developing countries are still the traditional manual methods.

The traditional methods of harvesting rice are the following, panicle and sickle harvesting. Harvesting and its related handling operations are significant points in the post production sequence because grain losses can be incurred. Each additional handling step produces a loss of 1 to 2 percent, for highly shattering varieties (Samson and Duff, 1973). The sequence of manual harvesting, field drying, bundling and stacking in traditional systems can incur losses of from 2 percent to 7 percent (Toquero and Duff, 1974). In-field transport which includes bundling of the cut stalks and done by using manually or animal-pulled sleds can incur losses ranging from 0.11 to 0.35 percent. Field stacking of the harvested stalks incurr losses ranging from 0.11 to 0.76 percent. The longer the stack is left in the field, particularly where the grain moisture content is high, the greater is the degree of loss.

2.6.1.2 Threshing Losses

Threshing losses vary with the manual threshing method or thresher used. A study in Indonesia suggested that short straw posed problems in feeding the pedal and mechanical threshers and left unthreshed grains at the base of the panicles (Djojomartono *et al.*, 1979).

Threshing methods of rice also varies greatly from country to country. The methods are generally classified as manual, animal or mechanical (FAO, 1997). One of the simplest systems for threshing rice is to pick up the sheaf of rice and strike the panicles against a hard surface.

Another frequently-used method of threshing rice is to trample it underfoot. If draught animals are available and there are large quantities of rice, threshing can be done by driving the animals (harnessed, in that case, to threshing devices) over a layer of sheaves about 30 cm thick.

This operation, which is also called "treading out", can equally well be accomplished with vehicles. This method of threshing rice is adopted in some Asian countries, using a tractor for power instead of draught animals.

2.6.1.3 Losses During Drying

Rice grains loss moisture based on their moisture content and the relative humidity of the air around it. If the humidity is low, high moisture rice will lose moisture until it comes to constant, low moisture content. If the humidity is high, low moisture rice will gain moisture (Thompson, 1998).

The extent of drying of harvested paddy rice depends on whether it will be stored for a short or long period or whether it is intended for milling. Drying can also be a stage where a lot of qualitative losses can occur if proper care is not taken.

The traditional method of drying the harvested rice crop is by drying it in the sun. The crop is either left in the field to dry after reaping before threshing, or spread out on mats or pavements after threshing. During the wet season, if there is no "artificial" drying capacity, it is not uncommon for the grain to sprout and rot before it can be dried. If there is any delay in drying, the wet grain becomes darker in color.

Most losses in drying occur because of either poor technical performance of the technology, or improper use of the technology, resulting in fissured grain. Fissured grain results in significantly lower milling recoveries.

It has been established that thermal stresses, high rates of moisture desorption, or moisture reabsorption by dried grains, all cause the rice kernel to fissure.

2.6.1.4 Storage Losses

Pest infestation due to insects, rodents, and birds is a real threat when paddy or milled rice is stored. There are measures to control infestation, such as the fumigation of the stock with phosphine gas.

Local private millers do not normally take any pest control measures. They accept the infestation loss. When the paddy is milled the insects are aspirated out, and the damaged grain is screened out.

2.6.1.5 Milling Losses

Milling rice is not actually a loss because rice is to be consumed milled. It is rather the different milling machines ability to produce high milling yields and the maximum head grains that matters.

Losses in the milling process are due either to inherent poor technical performance of milling machinery, or operator ineptitude, resulting in poor milling yields (De Padua,1999). An example of a milling technology that has been legislated out of existence in some countries is the Engleberg type single-pass one-step process, which is notorious for breaking the grain in the milling process and yielding as low as 53% milled rice.

Reported losses in milling should be distinguished between those caused by the drying process, and those due to the milling process itself.

The most significant breakthrough in the rice milling industry has been the development of the husking machines with rubber rollers, which significantly reduce grain breakage.

Modern milling plants now have 10 distinct steps in the process. Some setups are automated to reduce dependence on unskilled operators.

Davis (1994) reported that the optimum harvesting moisture content for paddy rice of Caloro variety was 20 to 24%. Quantitative or physical losses are manifested by low milling recovery while low head rice recovery or high percentage or broken grains reflects the qualitative losses.

Matthews and Spadaro (1976) found that rice breakage during the milling process increased with the decreasing kernel diameter. Dilday (1987) reported that rice breakage during the milling process decreased with the increasing paddy moisture content in the range of 12 to 16%. Luh (1991) reported that to have a high quality milling process with reasonable rice breakage, paddy must be harvested at the optimum moisture content and at the suitable stage of maturity. Clement and Seguy (1994) found that long and tiny rice kernels were more susceptible to breakage during the milling process.

Peuty *et al*. (1994) reported that paddy drying conditions affected the rice breakage during the milling process so that rice breakage rapidly increased with the decreasing moisture content of paddy drying air and that difference between paddy temperature and milling environment temperature decreased the performance of rice milling system. They also found that relative humidity of milling environment had significant effect on milling system yield.

Rice kernel breakage during the milling process is affected by different parameters such as paddy harvesting conditions, paddy drying, physical properties of paddy kernels, environmental conditions, and type and quality of milling system components.

Environmental conditions, such as drought, low sunlight intensity, disease, inadequate or excessive nitrogen and draining water early in hot weather, all intensify stress on rice kernels. The tendency of kernels to break under stress differs somewhat among varieties. The value of broken fractions varies with market demand, but high milling yield and low foreign material content may provide more income.

The implication of the different milling machines on the percentage of broken grains produced can have adverse implications on the rice farmer's income as whole or head grains rice have a much higher valued price than the broken rice in the market. Drying of paddy in artificial or mechanical dryers costs five to eight times more than sun drying (IRRI, 1997). This figure however is misleading. A drying facility that is part of a processing plant makes possible the production of better quality milled rice that will sell at a higher price per kilogram. A processing plant with a drying facility allows a business to buy paddy even during extended periods of rainy weather. In short, a progressive entrepreneur cannot afford not to invest in a drying facility.

Economic losses due to the poor quality of milled rice also occur. Economic losses are related to physical losses. Production of good-quality milled rice starts at the farm with good-quality seeds and good crop care for uniform growth and grain size. The other factors that affect quality, such as mixing of varieties, heat discoloration, contamination, insect damage in storage, fissuring in drying, and breakage in milling should be controlled in the post-production operations. The lack of appropriate technology, technical and management skills resulting in poor-quality milled rice output results in economic losses. The term grain quality has many meanings and is perceived differently depending on end use, field of interest, specialization, field of interest and ethnic background. In marketing, appearance is of foremost importance as a quality characteristic; producers and millers emphasize milling quality; food manufacturers insist on processing qualities; dieticians require nutritional qualities and consumers demand a widely cooking and eating qualities. Thus good quality and bad quality is greatly influenced by preference and when preferences differ, the same rice rate as good by one person may be rated poor by another.

Characteristics that influence rice quality include those under genetic control and those independent of genetic control, such as purity and cleanliness. These latter characteristics are primarily a function of handling and storage (USDA, 1999). Characteristics influencing milling qualities in rice include grain size, shape, weight, uniformity, milling yield and general appearance.

2.6.2 Major Causes of Post Harvest Losses in Rice

The causes of post-harvest losses, which some estimates suggest could range from 15 to as high as 50 percent of what is produced, are manifold. These include: harvesting at an incorrect stage of produce maturity, excessive exposure to rain, drought or extremes of temperature, contamination by micro-organisms and physical damage that reduces the value of the product.

There are many factors that cause post harvest losses in rice. Some of these factors can be controlled by the farmers whilst others like the climatic factors cannot be controlled by the farmer.

Post harvest losses can occur during any of the various phases of the post-harvest system. The loss may be quantitative or qualitative and also includes product deterioration. From an economic point of view, the sum of the losses in quantity and quality of the products inevitably means losses of money.

Post harvest losses could result from poor management of post-harvest systems. From the harvest onward, then, the grain undergoes a series of operations during the course of which quantitative and qualitative losses can occur. The sequence of these operations and the conditions in which they take place can, furthermore, create physical and biochemical phenomena that will bring about an alteration of the grain at later stages in the post-harvest system.

A late harvest, for example, can bring about losses from attacks by birds and other pests. Insufficient drying of grain can cause losses from the development of moulds and insects. Threshing can cause losses from broken grains and encourage the development of insects. Poor storage conditions can bring about losses caused by the combined action of moulds, insects, rodents and other pests. Poor transport conditions or defective packaging of grain can lead to quantitative losses of product (FAO, 2008).

In addition to these factors, there are others which can often be partly responsible for post-harvest losses, such as, marketing practices, sectoral policies and other socioeconomic aspects.

Post-harvest losses are the result of spillage, inefficient retrieval, inefficient processing of rice as well as inadequate machinery, poor operator skills, biological deterioration, and infestation by storage pests.

2.6.3 Strategies for Reducing Post Harvest Losses

A systematic analysis of production of all commodities including rice and handling system is the logical first step in identifying an appropriate strategy for reducing postharvest losses. It is important to select the technologies that are appropriate for the size of each postharvest enterprise (Kitinoja and Gorny, 1999; Kitinoja and Kader, 1995). Marketing companies and cooperatives are essential for handling produce and reducing postharvest losses by providing facilities for accumulating, preparing and transporting produce to markets; by coordinating marketing activities; and by distributing profits equitably to members.

Goletti (2003) listed the most relevant issues for developing countries as follows: the need for a regulatory framework that promotes growth while safe-guarding welfare; for adequate market information to be given to all participants involved; for further investment in postharvest research; and for participation in international agreements that promote trade and food safety. Also, a cost-benefit analysis to determine the return on investment in the recommended postharvest technologies is essential.

However, the major constraints continue to be high postharvest losses, poor marketing systems, weak research and development capacity, and inadequacies in policies, infrastructure, and information exchange. (Heyes, 2003).

Rice experts believe farmers could cut losses by altering production methods, such as moving from hand gleaning to mechanical harvesting. As with all agricultural decisions, however, the cost of an improvement is a deciding factor in its adoption. IRRI estimates the cost of its rat-catching system at US$400 per hectare, and it lasts just a few seasons. This can equal one third or more of the value of a rice crop, and may be too much for a farmer to pay (Quick, 1993). Governmental policies, too, are important to minimizing losses, especially where commodity crops like rice and corn are concerned. According to agronomists, policies that promote a stable, sufficient supply of these crops in an open, competitive marketplace stimulate food producers to be more efficient and quality conscious (De Padua, 1997).

The former West Africa Rice Development Association (WARDA) now known as the Africa Rice Center (ARC) has recommended that priority should be given to training programs to production and agric extension workers to prevent quality deterioration at the farm level and to gradually introduce quality standards both for paddy and milled rice.

2.6.4 Post Harvest Loss Assessment

Studies have been carried out by various agencies in almost all the rice growing countries. A loss assessment report by IRRI (2007), gave alarming large loss figures of up to 37%. The conditions under which these losses were estimated were not given. The field losses are usually actual physical grain loss measurements of grain that shattered or spilled. There are however projected losses based on potential yields. Storage losses may be based on samples where levels of pest infestation are measured. Drying and milling losses are usually derived loss estimates, or compared with control samples processed in the laboratory.

In reading loss figures, it should be borne in mind that loss assessment results are very much location specific, technology and practice dependent, and based on sample statistics. Unless the field conditions, or processing plant machinery type and condition are given, losses from different studies, or those made in different locations, or those done under different conditions cannot be compared. For example, it would be unscientific to claim gross improvements in the system by comparing loss estimates done in the 1970s with those done in the 1990s, unless the frame conditions for the loss assessment were similar. The usefulness of loss assessment studies is to make people aware of the need to allocate resources to post-production research, and to identify priority areas for research (De Padua, 1999).

The early high yielding varieties of rice shattered easily, and had short dormancy periods. Delays in harvesting caused significant losses. A crop harvested wet had to be immediately threshed and dried, or else it would germinate, discolor, or even rot. Field stacking of wet harvested rice makes the kernels turn yellow. In some countries, physical losses in the field from harvesting are almost insignificant. In Bangladesh, for example, gleaners will pick up every grain left in the field after harvesting (IRRI, 1997).

In general, manual harvesting has lower loss levels than mechanized harvesting (De Padua,1999). However, if manual harvesting is delayed due to a lack of labor, then losses would be incurred due to shattering of overripe grains. Threshing by trampling or beating does not cause major losses. However, as farm labor becomes scarce, reaping and threshing machines, or combines must be used. There is a trade-off between the need to mechanize and the higher level of losses with machines.

2.7 Importance of Post Harvest Studies of Rice

Rice producers can significantly increase their incomes from their rice crops if they can reduce physical losses throughout the post harvest chain, store their rice until they can get a better price in the off season and produce better quality which in most markets also translates into a higher price. Postharvest losses in food crops occurring during harvesting, threshing, drying, processing, storage and transportation have been estimated to claim between 30 and 40% of all food crops in developing countries (Saunders *et al*., 1978). Experts have predicted that the most efficient way to increase food availability is to control the losses occurring between the field and the consumer. Consumers' demand for cosmetically perfect produce often means that much of the food successfully harvested is wasted.

Addressing the problem of postharvest losses is complicated because losses occur in so many different ways; yet some recent efforts have shown promise. For example, a number of strategies have targeted losses during food storage, especially directly after harvest when foods' internal moisture is being reduced and they are prone to attack by insects and other pathogens. In one experiment in Benin, hermetically sealing storage containers of beans and soybeans asphyxiated insect larvae that had infested the beans, cutting losses substantially. Also in Benin, yam losses fell significantly when the tubers were stored in elevated structures that maintained an ideal humidity level.

These losses results in higher prices for consumers and place greater pressures on the farmers to produce more to compensate, which has a negative effect on the environment (FAO, 2009).

The lack of awareness of producers of the significant economic losses incurred during post harvest handling had made them not to take extra care in minimizing such losses. It is important to conduct a research on this issue to estimate the losses quantitatively and economically in creating the needed awareness in The Gambia so as to come out with a way forward to reduce post harvest losses in order to achieve food security.

Food losses contribute to high food prices by removing part of the supply from the market. They also have an impact on environmental degradation and climate change as land, water, human labor and non-renewable resources such as fertilizer and energy are used to produce, process, handle and transport food that no one consumes. Another major problem, further highlighted during the 2008 food crisis, is the inadequate and insecure storage facilities in many developing countries.

If post harvest losses are assessed, the nature, causes and amount of loss could be determined. Provision of good storage enhances the shelf life of the produce as well as reduces losses. This situation was observed in Guinea (FAO, 2008) when silos were provided, losses were reduced by 15 to20%.

Dozens of artisans were trained in the construction and installation of silos. As a result, farmers were able to reduce losses in their grain stocks to a minimum and defer sales until better market conditions prevailed.

With world population expected to near its peak in 2050 and greater urbanization in many developing countries, meaning higher-value food will have to be moved over longer distances, greater efforts are needed to reduce significantly food losses in the entire food chain. At the very least, there will have to be significantly greater investment in storage infrastructure and first-stage processing equipment.

2.8 Post Harvest Research and Development

Several authors have presented a strong argument in favor of devoting more resources to postharvest research and development efforts in developing countries (Bourne, 1983; Mukai, 1987; Okezie, 1998). Although minimizing postharvest losses of already produced food is more sustainable than increasing production to compensate for these losses, less than 5% of the funding for agricultural research is allocated to postharvest research areas (Kader, 2003). Goletti and Wolff (1999) stated that "while research on the improvement of agricultural production has received considerable attention and funding, until recently postharvest activities had not attracted much attention from international research organizations (CGIAR, FAO, ACIAR, IDRC, GTZ, CIRAD, NRI, USAID).” They identified the following five reasons to justify an increased commitment to postharvest research by the international agricultural system:

1) High internal rates of return,

2) International public good character,

3) Effect on poverty,

4) Effect on food security and health, and

5) Effect on sustainable use of resources.

Goletti and Wolff (1999) concluded that: “As the significant contribution of postharvest research to CGIAR goals such as poverty reduction, food security and sustainability becomes clear, and in the light of high rates of return, the very skewed allocation of funds to production versus postharvest topics cannot be justified. Since so far, relatively little has been invested in postharvest research, there is potential for large impacts as constraints and bottlenecks are removed. It would thus be desirable to reexamine current funding priorities and to allocate a larger proportion of resources to the postharvest area.”

Minimizing postharvest losses of food crops is a very effective way of reducing the area needed for production and/or increasing food availability. Solving the postharvest food distribution problems in a given country will require cooperation and effective communication among all the research, extension, and industry personnel involved. Postharvest horticulturists need to coordinate their efforts with those of production horticulturists, agricultural marketing economists, engineers, food technologists, and others who may be involved in various aspects of the production and marketing system. In most cases, solutions to existing problems in the postharvest handling system require use of available information and application of available technologies at the appropriate scale rather than conducting new research, or developing new technologies. Overcoming the socioeconomic constraints is essential to achieving the goal of reducing postharvest food losses.

2.9 Grain Quality Parameters

Head grain is grain that does not contain damaged grain, dead rice, immature grains, grains of other crops and foreign matter, and is evaluated for quality by comparison with standard samples for inspection. Head grains are those that have completed maturation. Grains with a higher head rate have a higher milling yield.

The typical high yielding variety (HYV) medium-to long-grain Indica variety has 20% hull (or husk), and 10% bran layers. The theoretical milling yield of polished grain should therefore be 70%. State-of-the-art commercial mills, properly adjusted and working with good quality paddy, can yield 67% milled rice, with head rice (3/4 to whole grains) above 70%. Poor quality paddy that is badly fissured can lower total milling yields to as low as 60%. Much of the grain endosperm is reduced to rice flour that goes with the bran, or to brewers' rice that is separated from the commercial milled rice output by sifters. The bran and rice flour, and small broken grains, are used as animal feed. Much is already known about the causes of fissuring. Unfortunately the basic principles of proper drying are not yet widely known in the industry.

Broken grains on the other hand are those that turned out to be two thirds to one quarter of the length of a complete grain.

Head rice recovery is one of the most important factors in determining a grower's income. Since rice is consumed and processed mainly in whole kernel form, the physical attributes of the intact endosperm are always of foremost importance for its market price. Uniformity in the physical dimension such as grain length, breadth, shape and weight also affects its market value. Most of these traits are under genetic control. Example, grain length has been reported to be controlled by one gene (Ramiah *et al.*, 1931), two genes (Bollich, 1957), three genes (Ramian and Parthasarathy, 1933) or polygenes (Mitra, 1962; Chang, 1974; Nakatat and Jackson, 1973; Somrith *et al.,* 1979). Similarly, breadth, shape and grain weight have been reported to be polygenic in inheritance (Ramiah and Parthasarthy, 1933; Nakatat and Jackson 1973; Chang, 1974; Somrith *et al.*, 1979). Hereditory of polygenic traits varies from very low to very high (Beachell and Malick, 1957).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The research was conducted at "NOBEWAM" and "BESEASE" in the Ejisu-Juabeng District in the Ashanti Region of Ghana.

3.2 Experimental Procedure

The experiment was done in two phases; a survey and a field work.

3.2.1 Survey

The survey on farmers' perception and knowledge of post harvest losses of rice was conducted at Besease in the Ejisu Juabeng District of the Ashanti Region of Ghana. A semi structured questionnaire aimed at investigating some rice farmer's perception about post harvest losses of rice was administered to twenty rice farmers in "Besease" a rice farming community in the Ashanti region of Ghana. The survey was aimed at seeking information from the rice farmer's about their perception of post harvest losses and the stages at which they experienced most post harvest losses. Information on farmers perception of methods of reducing postharvest losses was collected. Other important information collected included the causes of post harvest losses and the estimation of post harvest losses.

3.2.2 Field Experiment

A national seed multiplication site at Nobewam by CSIR-CRI with NERICA 1and NERICA 2 varieties was used in the study. A field experiment was also carried out at Nobewam and rice varieties grown were NERICA 1 and NERICA 2. Cultural practices carried out on the field included land clearing, ploughing, retovation, and direct seeding, weeding, fertilizer application and bird scaring. After maturity of the crop, harvesting, threshing, drying, storage and milling were carried out to determine the post harvest losses that were involved in those stages. For each variety, an area of 4x5 meters was demarcated for cultivation. There were three replications per variety.

3.2.3 Experimental Design

A randomized complete block design (RCBD) was used for the experiment. A 2x2 (two varieties and two harvesting methods) with three replications was used for determining the harvesting losses of two varieties NERICA 1and NERICA 2 using two different types of harvesting methods; panicle and sickle.

3.3: Post Harvest Studies

3.3.1: Determination of Harvesting Losses

Skilled harvesters were hired to harvest a given area in their own usual way of harvesting using panicle and sickle harvesting.

Left-over rice on the harvested plots were thoroughly collected, cleaned, dried, weighed and stored in a cloth bag. Percentage harvesting losses were determined by the weight of paddy rice left on the field at a harvested area divided by the total harvested paddy of that particular area multiplied by 100. For farmers grown fields
(5), harvesting was done using sickle as that was their major harvesting method.

3.3.2 Determination of Threshing Losses

Threshing is the removal of grain from the cut straw after harvest and is closely related to harvesting operations. Two different types of threshing methods were used based on the method of harvesting employed: bag-beating (panicle) and bam-bam (sickle). Panicle harvested rice were put in a bag and beaten with stick to separate the grains from the stalks. Rice harvested with sickle was threshed using the “bam bam” a locally made wooden box with a tarpaulin beneath it. In this method, the rice stems were held and the stems together with the panicles on them were beaten against an inner side of the box. Removed grains were allowed to drop onto a tarpaulin beneath the box.

After threshing, all the rice grains that fell out and were found around the wooden box were collected, cleaned, dried and weighed and all rice grains remaining on the stalks after the beating were also collected, cleaned, dried and weighed. Threshing losses were also assessed on five different farmers fields using the sac beating method.
Threshing losses were calculated using the formula:

Threshing losses = [weight of left over grains /total weight of collected grains] x 100.

3.3.3 Weight Losses During Drying.

Ten kilograms (10kg) of paddy rice was spread on a drying floor according to farmers practice and sundried. An experienced farmer was allowed to gather and collect the dried rice. The grains that were left on the floor (after the farmer had finished gathering the dried rice) were collected. Drying losses were determined based on the formula:

Weight Loss During Drying = [weight of left over paddy/weight of collected rice] x 100.

3.3.4 Determination of Weight Loss During Storage.

Dried paddy rice of NERICA 1 and NERICA 2 were placed in rice sacs and stored for 60 days. At the end of the 60-day period, the pre-weighed bags of rice were reweighed. Storage losses were calculated using the formula:

Percentage weight loss during storage = [(initial weight of paddy rice - final weight of paddy rice)/initial weight of paddy rice] x 100

The determinations were carried out in triplicates and means taken.

3.3.5 Milling Yield

The performance of three different milling machines (SB 30, SB 10 and a local machine (Engelberg) shown in Figure 3.1) were assessed on their rice milling yields. Rice milling yield refers to the amount of polished white rice obtained from unhusked rice. Rice milling rates for polished rice varies by crop variety and quality, but tend to average about 72% of rough rice in the United States (http://enwilkipedia.org./wiki/milling-yield). Each machine was used to mill 25 kilograms of NERICA 1 and NERICA 2 paddy. Milling was done in triplicates. The resulting rice, bran and husk from each milling machine were collected and weighed. Milling yield was determined using the formula:

Milling yield = [weight of white rice/weight of paddy] x 100.

SB 30 SB 10 Local

Figure 3.1: The three different milling machines used during the experiment

3.3.6 Assessment of Different Millers

The performance of three different millers were assessed to determine their influence on milling yield. Three different millers were allowed to mill triplicates of 25 kilograms of paddy rice using an SB 30 milling machine. Milling yield of the different millers was determined as in 3.3.5 and compared.

3.4 Analysis of Milled Rice

The grains after milling were subjected to head grain count to determine which of the milling machines produce more breakages. Ten grams (10 grams) of milled rice from each sample was taken. Head grains (unbroken grains) were separated from the broken grains and weighed. The percentages of broken and unbroken grains from each machine were determined. The 1000 grain weight of the milled rice was also assessed by weighing 10g of rice from each sample and count the total number of grains in the ten grams using the formula below.

Thousand grain weight=1000 x 10/ (the number of grains in the 10g sample)

Source:(http://www.researchintouse.com/nrk/Rivinfo/output/R8263_Training manual.pdf)

3.5 Statistical Analysis

The Statistical Package for Social Sciences (SPSS) version 17 was used to analyze the responses on farmer's perception of post harvest losses.

Analysis of variance (ANOVA) was performed on experimental data collected using GENSTAT Discovery Edition 3 and separation of treatment means was done using the LSD at 5% level of significance.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Survey; Farmers Level of Awareness of Postharvest Losses of Rice

A survey was conducted to determine the level of knowledge and farmers awareness of some rice farmers on post harvest losses of rice from harvesting to milling. Twenty (20) rice farmers in "Besease" were interviewed. The results of the survey indicated that most (55%) of these farmers were aged between 40 and 49 years as shown in figure 4.1. This suggest that most of the rice farmers were middle aged. On the other hand, 45% of the farmers were aged between 20 and 39 years. This means that farmers were energetic and have the potential of growing the rice industry.

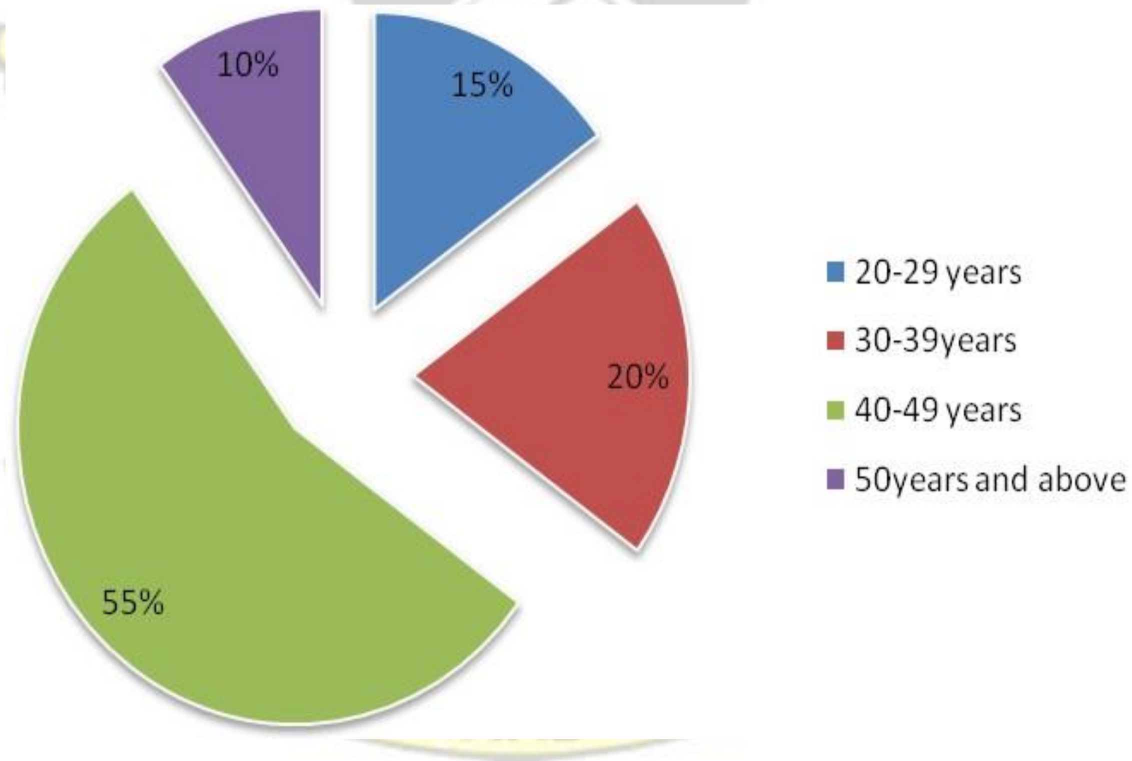

Figure 4.1: Age distribution of the farmers

According to the survey, farmers have been growing different varieties of rice which are all believed to be improved rice varieties like "*Togamasha*", "*Unclebens*", "*Sikamo*", "NERICA" and "WITA 7" (Figure 4.2) varieties in both the lowland and swampy ecologies and have experienced post harvest losses in all the varieties.

Figure 4.2 shows the percentage of farmers growing various rice varieties. Most (60%) of the farmers indicated that they grew their rice in lowlands while the rest (40%) grew their rice in swampy ecologies as presented in Figure 4.3. The majority (35%) of the farmers indicated that they have been in the production of rice for between ten to fourteen years followed by 25% who had farming experience of five to nine years in rice.

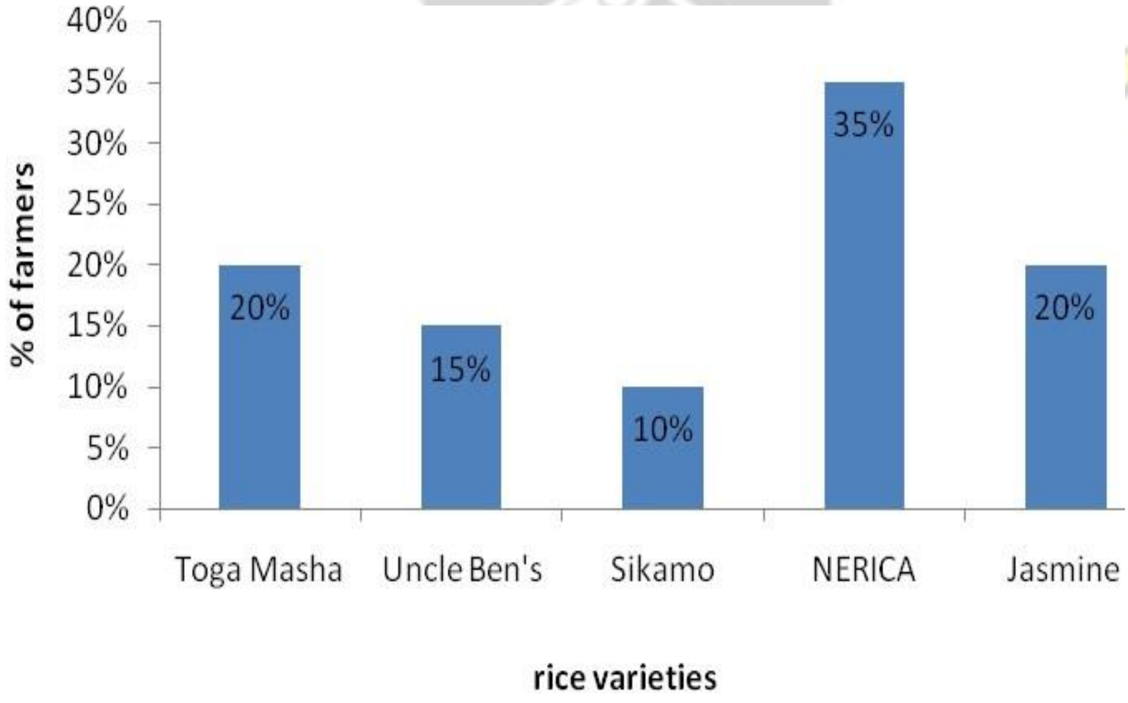

Figure 4.2: Different types of rice varietes grown

Farmers who have experience between 15 years and 19 years constituted 20% of the respondents. The farmers who had cultivated rice for twenty years and above also constituted 20% of the respondents. These results show that the farmers were experienced in the cultivation of rice and when they are properly resourced could help grow the rice industry.

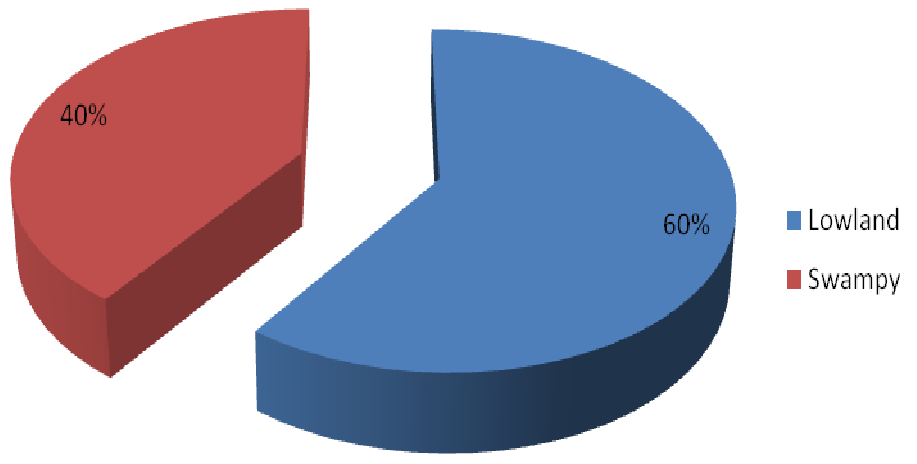

Figure 4.3: Ecologies where farmers grow rice

Farmers experience of postharvest losses varied. Ninety five percent (95%) of the respondents reported that they had experienced postharvest losses of rice whilst the remaining 5% said they had not. According to the farmers, most post harvest losses in rice production from harvesting to milling equally occur at threshing and milling stages. Thirty percent (30%) of the respondents indicated that the highest losses occur during threshing while another 30% reported that the highest losses were at milling. The results also showed 25% of the farmers experiencing post harvest losses at the harvesting stage, 10% of farmers at the transportation stage and the remaining 5% at the winnowing stage as shown in Figure 4.4. The farmers also reported that the causes of losses were as a result of flooding of rice fields during harvesting when there are heavy rains; insufficient post harvest machinery, birds attack on the rice field, the use of manual labor, rice shattering at harvesting, rice paddy getting moldy during drying because of poor sunlight intensity and short duration of sunlight especially during the rainy season; as well as rice grain breakage during milling.

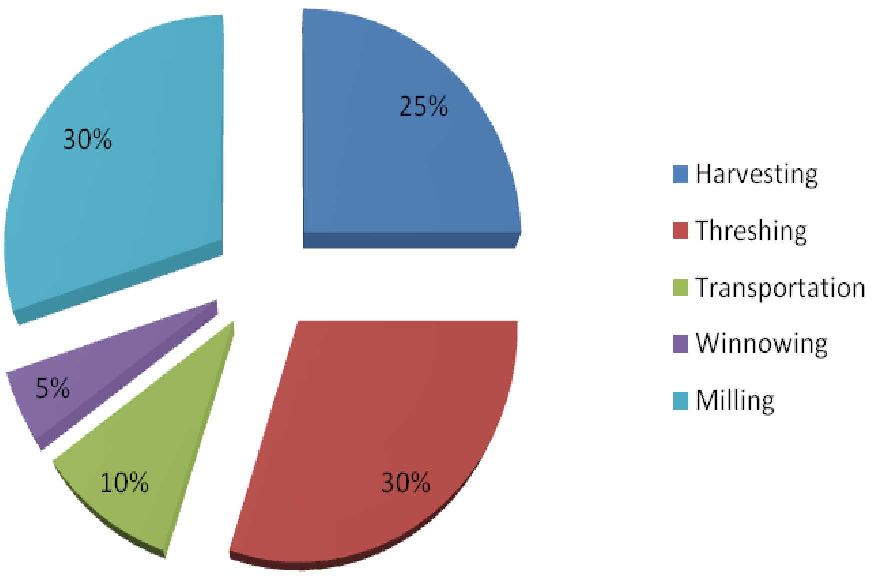

Figure 4.4: Stages at which post harvest losses occur.

Losses at the entire production chain varied among respondents Thirty five percent (35%) of the respondents reported that they incur a total post harvest losses of 40% and above; 35% indicated that losses ranged between 30 and 39% ; while 15% reported 20% to 29% losses (Figure 4.5). The remaining 15% lost between 0 and 19%. These losses were regarded as being too high by the majority (90%) of the respondents. However, the remaining 10% consider such losses as normal (Figure 4.6). From the responses, it is obvious that the perceived losses were unacceptably high. The implication is that the rice farmers lose huge amounts since 70% of the rice farmers reported losses of 30% and above. It is therefore important for stakeholders in the local rice industry to address the phenomenal losses to enable the growth of the industry and alleviate poverty among the farmers.

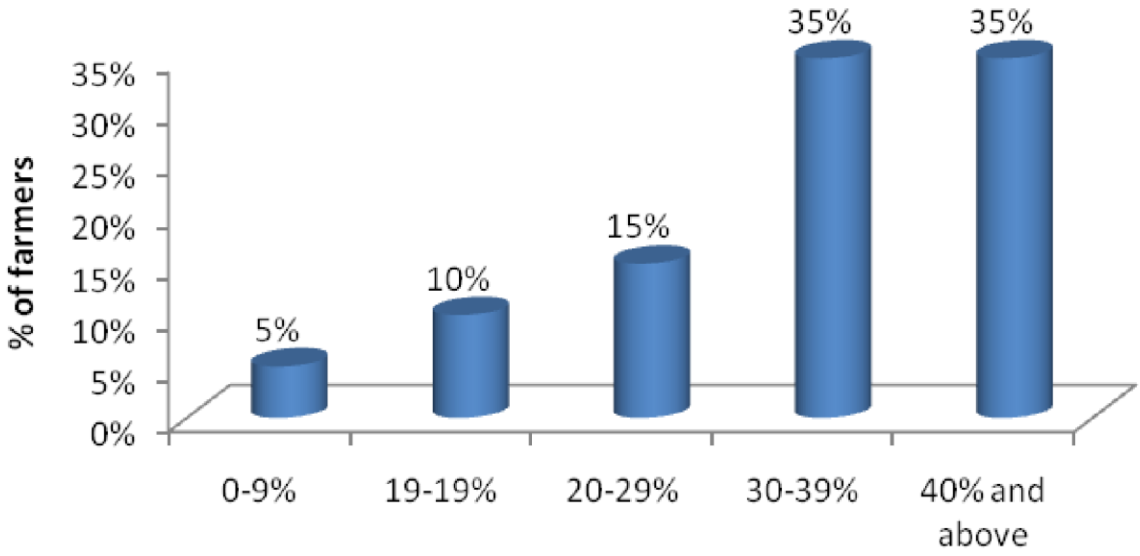

Figure 4.5 Percentage post harvest losses of rice from harvesting to milling

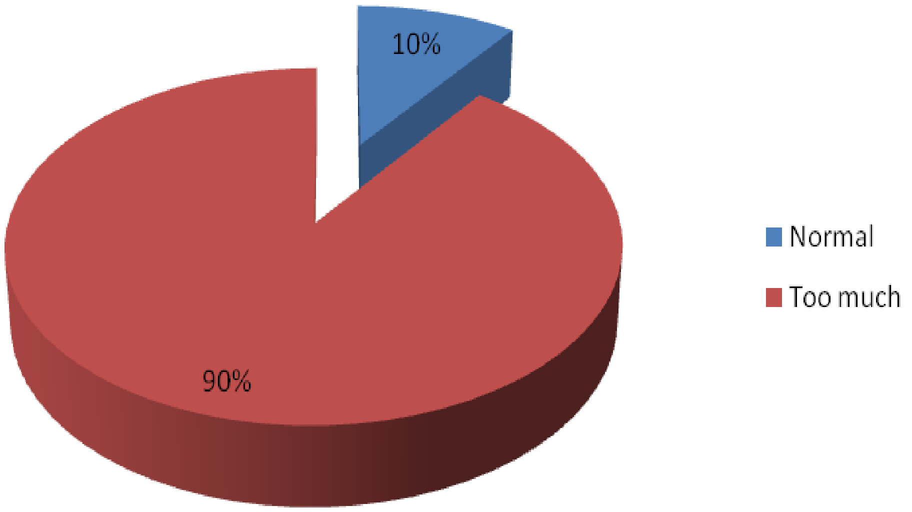

Figure 4.6: Perception of farmers about post harvest losses of rice

In attempting to reduce the above post harvest losses, 65% of the respondents have a strong believe that the problem of high post harvest losses of rice can be significantly reduced through mechanization. Unfortunately, the farmers reported that they did not have access to mechanized technologies and facilities. However, 15% of the farmers indicated that since they lacked the technical know how on post harvest loss reduction, training in post harvest handling of rice would be the most essential element in helping to reduce the high post harvest losses. Another 15% of the farmers interviewed suggested that provision of financial support through loans by the government of Ghana through the Ministry of Food and Agriculture would help them acquire appropriate inputs and efficient post harvest machinery such as combined harvesters, threshers, tractors for rice transportation and loans to hire laborers.

Surprisingly, 5% of the farmers believed that post harvest losses were natural phenomenon occurring in all crops and therefore nothing can be done to reduce them.

According to them, they will not waste resources controlling the losses.

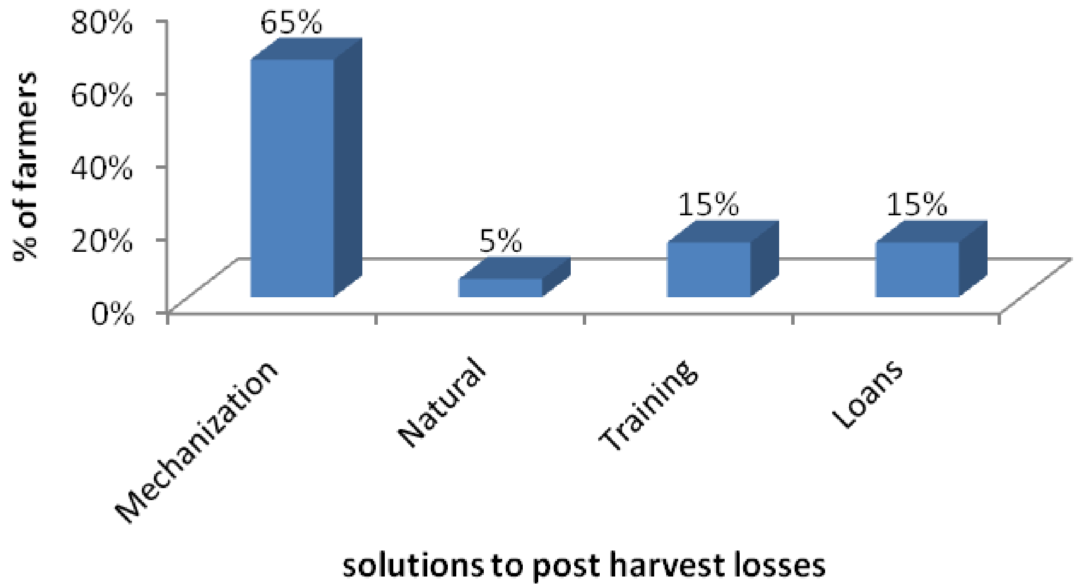

Figure 4.7: Suggested solutions to post harvest losses

The above survey results has highlighted the fact that rice farmers are aware of the post harvest losses involved in rice cultivation and are interested in reducing these losses where ever and whenever possible. The implication of these findings is that Government institutions that are endowed with the development of the agricultural sector should endeavor to train rice farmers on proper post harvest handling methods of rice which would help minimize post harvest losses of rice.

4.2 Field work; harvesting losses

A triplicate demarcation of a 4x5 meter area on the rice field was made for the assessment of harvesting as well as threshing losses. Panicle and sickle harvesting methods were carried out and losses were estimated.

Results of the harvesting losses have been presented in Table 4.1. Harvesting losses between the varieties (NERICA 1 and NERICA 2) were not significantly different. However, losses due to the methods of harvesting (panicle and sickle) were significantly different. The use of panicle harvesting method resulted in 1.39% grain loss whilst there was 2.93% loss when sickle harvesting method was used. This indicates that panicle harvesting should be the method of choice based on the figures for harvesting losses. There were significant differences in harvesting losses due to the interaction between the variety and method of harvesting. Panicle harvesting for NERICA 1 resulted in the least harvesting loss (1.13%) while the highest loss was in the interaction between NERICA 1 and sickle harvesting (3.25%).

Generally, harvesting loss values of (1.13-3.25%) reported in this study falls far below than the 12.05% harvesting losses that were found on some farmers fields during this research work in Ghana but falls within range (1-3%) reported for South East Asia (IRRI,1997). The results of the survey presented earlier also showed that 25% of the farmer respondents had reported that the highest losses in rice occur during harvesting (Figure 4.4). However, the field loss assessment research seems to debunk this perception. Even though panicle harvesting is seen to result in minimum post harvest losses when compared to sickle harvesting, it is important to note that harvesting by sickle is twice much more faster than panicle harvesting and therefore it might not be advisable for a large scale rice farmer to practice panicle harvesting due to the time and labor cost implications. Apart from these delays in harvesting, it ultimately results in higher losses as a result of birds attack and inappropriate moisture content of paddy. Even though harvesting losses were lower when panicle harvesting was used, the cost of the extra man hours, time spent as well as other extra resources spent on harvesting does not make the gain in panicle harvesting economical. Farmers therefore might still be better off harvesting with sickle in the absence of improved mechanized harvesting.

Table 4.1: Harvesting Losses in NERICA 1 and NERICA 2 rice varieties using two kind of harvesting methods; panicle and sickle.

(a) Total weight of harvested rice (g)

Treatment/Variety	NERICA 1	NERICA 2	Mean
Panicle	6450	6409	6430
Sickle	6925	7443	7184
Mean	6688	6926	

Lsd(P<0.05) Varieties=1692.4

Lsd(P<0.05) Harvesting Method=1692.4

Lsd(P<0.05) Varieties x Harvesting=2393.4

CV%=21.8

(b) Percentage harvest loss

Treatment/Variety	NERICA 1	NERICA 2	Mean

Panicle	1.13	1.64	1.38
Sickle	3.25	2.62	2.93
Mean	2.10	2.33	

Lsd(P<0.05) Harvesting Method= 1.34%

Lsd(P<0.05) Harvesting x Variety= 1.89%

CV%= 32.3

4.3 Threshing losses

Sickle harvested rice from both NERICA 1 and NERICA 2 were threshed using the locally made wooden box commonly called the "bambam" method. Since in panicle harvesting only the panicles are cut, the harvested rice does not come with the stalks as in the case of sickle harvesting to enable threshing using the wooden box (bambam) method. Threshing for the panicle harvested rice therefore done using the bag-beating method instead.

Even though the NERICA 2 variety had lower threshing losses (3.94%) compared to the NERICA 1 variety (4.65%), the difference was not significant. Looking at the values of the result of the different threshing methods, threshing losses were higher (6.14%) in the sickle-harvested rice that used the "bambam" than in the panicleharvested rice (2.45%) that used the bag beating method. This outcome is attributable to the different methods of harvesting (sickle or panicle) which dictated the threshing methods (bambam or bag-beating) that had to be used. The losses were lower in the bag beating method because very little grains escaped from the bag. However, in the "bambam" method, there was scattering of rice from the collecting box. Threshing in an enclosed room might help reduce threshing losses especially in the “bambam” method since scattered grains can be collected.

The interaction between variety and threshing method resulted in significant differences in the threshing losses. When the bag-beating method was used for threshing, NERICA 2 had significantly lower losses (0.92%) than NERICA 1 (3.98%). On the other hand when the bambam method was used there were no significant difference between the varieties NERICA 1 and NERICA 2. Generally the bambam method resulted in higher threshing losses (between 5.33 and 6.96%) than the bag beating method (between 0.92 and 3.98) variety notwithstanding. These values are lower than 4-6% threshing losses reported for South-East Asian countries
(IRRI, 1997). These lower values seem to contradict the claim of the rice farmers (30%) that the highest losses occur at threshing (Figure 4.4)

Table 4.2: Percentage Threshing Losses of NERICA 1 and NERICA 2 rice varieties under two different threshing methods; Bag beating and “Bambam” methods.

Variety/Treatment	NERICA 1	NERICA 2	Mean
Bag beating(Panicle)	3.98	0.92	2.45
Bambam (Sickle)	5.33	6.96	6.14
Mean	4.65	3.94	

Lsd(P<0.05) Threshing Method=1.47%

Lsd(P<0.05) Varieties x Threshing Method=12.8%

CV%= 12.8

4.4 Harvesting and Threshing Losses at Five Different Farmers Fields

Five different rice farmers' fields with different rice varieties, mostly the NERICAS and *Sikamo* rice varieties were also assessed for harvesting and threshing losses using a 4x5m area.

On farmer fields harvesting losses ranged between 3.03% to 12.05% while threshing losses also ranged from 0.53% to 4.07% (Table 3). Total losses due to only harvesting and threshing losses at farmer's fields ranged between 5.60% and 16.14%. The different post harvest losses between farmers are due to the way they control weeds on their rice fields because the presence of a lot of grass on the rice field can affect the effectiveness of harvesting. The differences could also be attributable to wide variations in the skill of harvesting and threshing.

Table 4.3: Harvesting And Threshing Losses At Farmer's Fields

Parameter	Harvesting losses(g)	Threshing losses(g)	Total weight of harvested rice (g)	Harvesting losses (%)	Threshing losses (%)	Total losses (%)
Farmer1 (NERICA)	382	35	4837	7.91	0.73	8.65
Farmer2 (NERICA)	135	50	1164	12.05	4.07	16.14
Farmer3 (NERICA)	198	211	7773	2.60	3.00	5.60
Farmer4 (*Sikamo*)	299	144	3723	8.20	3.73	11.93

Farmer5 (NERICA)	177	36	7124	3.03	0.53	3.57
Lsd(P<0.05)	**171.6**	**72.5**	**3421.5**	**5.44**	**1.95**	**4.57**
CV%	**39.6**	**43.4**	**38.2**	**44.2**	**44.5**	**27.4**

4.5 Storage Losses

Two rice varieties (NERICA 1 and NERICA 2) were harvested, threshed, dried, weighed and stored in rice bags for 60 days in a well ventilated room and under ambient temperature after which they were weighed at the end of the storage. Rice storage pest were found in the stored rice after the storage period and the pest were isolated and identified at the Entomology Laboratory of the Faculty of Agriculture of the Kwame Nkrumah University of Science and Technology, Kumasi as *Sitophyles Orizae*. There were weight losses in both varieties (NERICA 1 and NERICA 2) ranging between 6.19% and 9.35% (Table 4.4). The reduction in the weight therefore was due to both moisture losses of the grains during storage as well as pest or insect infestations. The storage losses observed is higher than reported by IRRI at 2 to 6% for South East Asia (IRRI, 1997). Proper drying and pest control are important to minimize storage losses.

Table 4.4 Storage losses of NERICA 1 and NERICA 2 after 60 days.

Variety	Initial weight(g)	Final weight (g)	% loss
NERICA1 (Panicle harvest)	6450	6053	6.07
NERICA 1 (Sickle harvest)	6925	6277	9.26
NERICA2 (Panicle harvest)	6409	6019	5.97

NERICA 2 (Sickle harvest)	7443	6933	6.79
Lsd(P<0.05)	**3415.5**	**3088.0**	**3.29**
CV%	**26.6**	**25.9**	**24.9**

4.6 Drying Losses (Left over grains after Drying)

An average drying loss of 1.66% (Table 4.5) was recorded during the drying loss assessment. This result is within range of 1-5% reported by IRRI (1997) for some South East Asian countries. Drying losses of rice is not variety dependent. However, it is dependent on farmer skill. The loss figure indicated is low compared to losses at other postharvest stages.

Table 4.5 Postharvest Losses Of Rice At Drying

Farmer	Quantity of rice dried (g)	Drying losses (g)	% drying losses
1	10000	157	1.57
2	10000	176	1.76
3	10000	165	1.65
Average	**10000**	**166**	**1.66**

4.7: Total post harvest losses of rice at harvesting, threshing, drying and storage.

In all, the field work showed the total post harvest losses at the above stages as;

Table 4.6 Total Post Harvest losses

Activity	Percentage losses
Harvesting losses	3.03 to 12.05
Threshing losses	0.53 to 4.07
Weight loss at Drying	1.57 to1.76
Storage losses	5.97 to 9.26
Total	**11.10 to 27.14**
Average	**19.12**

The total losses of rice in this study from harvesting to milling has been presented in Table 4.6. There were variations at each stage. Harvesting losses ranged between 3.03 and 12.05%. Threshing losses varied between 0.53 and 4.07% while drying losses ranged narrowly between 1.57 and 1.76%. Losses during storage varied between 5.97% and 9.26%. All together the total losses from harvesting losses to storage were between 11.1% and 27.14%. This overall loss estimate of up to 27% observed in the field experiment is similar to those reported by 25% of the farmers (figure 4.5) The observed overall losses of up to 30% is indicative that much is lost since this reflects 30% of lost revenue, labor, man hours, food (rice), land as well as the other factors of production employed during production. All stake holders should address these high losses. Appropriate capacity building inputs and machinery are crucial in redressing these losses.

4.8 Milling Efficiency of Milling Machines

Milling yield depends partly on moisture content of the paddy to be milled. The moisture content of the rice was taken. Three different milling machines, (SB10, SB30 and a locally manufactured machine (LMM)) were used to mill paddy rice at 12% moisture content and the 12% moisture content was within the recommended 12-14% range (Afazaliina *et al*., 2002) to determine milling performance of the machines and millers. Each milling machine was used to mill a triplicate of 25kg paddy. The results of the milling analysis have been presented in Table 4.7. The results showed that SB30 had marginally higher milling yield (67.32%) as against the SB10 (66%) although the difference was not significant. However, the differences between the milling yields of either the SB30 machine and the locally manufactured milling machine or that of the SB10 machine and the locally manufactured milling machine were significant. The locally manufactured milling machine had the lowest milling yield (63.32%). This implies that the locally manufactured milling machine was less efficient as it also resulted in higher percentage (52.9%; Table 4.8) of broken grains. The high breakage of by the local milling machine is due to the fact that whilst the SB30 and the SB10 machines have rubber rollers, the local milling machine has steel rollers. The observation is that the locally made machine produced less white rice per unit weight of paddy. This results in less recoverable rice and therefore less revenue. SB 30 is therefore superior to SB 10 and the Local machine (Engelberg) in terms of milling yield.

Table 4.7:Milling Efficiency Of Different Milling Machines Used By The Farmers.

Machine	Milling yield %	Bran weight %	Husk weight %
SB 30	67.30	14.53	18.13

SB 10	66.0	17.87	16.13
LLM	63.33	36.67	0
Lsd(P<0.05)	**4.37**	**3.4**	**1.64**
CV %	**3.3**	**8.7**	**7.2**

4.9 Performance of Different Millers

The milling yield from the three different individual millers ranged from 66.8% to 68.53% (Table 4.8). The results were obtained by allowing the millers milled from the same milling machine SB30. The different millers showed significant differences in their abilities or skill in milling. This indicates that milling depends on the millers skill and this observation is in agreement with the report that milling is more of an art than a science (Pominski *et al*., 1961).

Table 4.8. Effect of different individual millers on milling yield of rice.

Millers	Milling yield %	Bran weight %	Husk weight %
1	66.80	13.73	19.47
2	68.53	13.60	17.87
3	67.20	13.20	19.60
Lsd(P<0.05)	**3.61**	**2.13**	**2.83**
CV%	**2.7**	**7.9**	**7.5**

4.10 Grain quality of rice from the three milling machines

The effect of the milling machine type on some selected quality characteristics of milled rice was assessed. There were significant differences (Table 4.8) in the ability of the milling machines to produce unbroken grains (headgrains). The results showed that

SB30 produced the highest (67.3%) percentage of unbroken grain, followed by SB10 (50%). The locally manufactured machine (LMM) produced the least (47.1%) percentage of unbroken rice grains after milling. The differences between SB30 and SB10 as well as between SB30 and LMM were significant. The performance of SB10 and the LMM were statistically not different from each other.

In the Japanese inspection standard for a 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 (NFA, 1980). Clearly, the levels of broken grains obtained in this study with SB30, SB10 and LMM were much higher than the internationally set standards. This outcome also indicates that the rice which was milled using the SB30 machine which had the best performance with regards to rice output and head grains count is far below the above standards as it has about 33% of broken grains while SB10 had 50% and LMM had 53%. The observed values are alarming since the rice milled using the available milling machines in Ghana might not qualify even for the lowest grades in the international market (15%, Japan; 25 %, USA). The implication of this observation is that the milling machines used in Ghana will not produce milled rice that falls in the acceptable grading standard of America and Japan. In this respect, Ghana milled rice might not compete very well with Japanese or American rice if they are all at the same market where unbroken grains is mostly demanded. Consequently, Ghanaian rice farmers might not get competitive prices for their rice on the international market.

Table 4.9: Effect of milling machine type on head grains after milling

Machine	Number of grains in 10g	Weight of one unbroken grain (g)	Weight of broken grains (g)	Weight of unbroken grains (g)	unbroken grains(%)	broken grains(%)
(SB30)	734	0.2277	3.60	6.73	67.3	32.7
(SB10)	836	0.1970	5.00	5.00	50.0	50.0
(LMM)	855	0.2023	5.27	4.73	47.3	52.7
Lsd(P<0.05)	**105.5**	**0.05**	**1.37**	**1.30**	**13.00**	**13.01**
CV%	**6.5**	**11.1**	**14.8**	**11.8**	**11.8**	**14.8**

Table 4.10: Effect of milling machine type on 1000 grain weight after milling

Machine	Number of grains in 10(g)	Weight of one unbroken grain	1000 grain weight
SB 30	734	0.2277	13.62
SB 10	836	0.1970	11.96
LMM	855	0.2023	11.69
Lsd(P<0.05)	**105.5**	**0.05**	**1.631**

Thousand grain weight=1000 x 10/ (the number of grains in the 10g sample)

Source: (http://www.researchintouse.com/nrk/Rivinfo/output/R8263_Training manual.pdf)

CHAPTER FIVE

5.0: CONCLUSIONS AND RECOMMENDATIONS

5.1: Conclusions

The survey has revealed that about 90% of the rice farmers interviewed indicated that they experienced postharvest losses of rice and that the losses were very high. Respondents also reported that the problem of lack of post harvest machinery was the major problem resulting in the high post harvest losses of rice. According to the rice farmers, mechanization of the post harvest activities, providing technical knowhow and access to financial resources to acquire appropriate inputs and machinery could help reduce the losses in rice

Harvesting losses were higher when the sickle method of harvesting was used than when the panicle harvesting method was used. Threshing losses were also higher in sickle harvesting where threshing using the “bambam” method was applied.

The storage losses was as high as 9%. The SB 30 milling machine performed significantly better than all the other machines in terms of both milling yield and head grain quality.

From the results obtained during the study, post harvest losses of rice during harvesting, threshing, drying and storage ranges between 11 and 27%; transportation, winnowing and handling losses were not included. The loss figures are very high. All efforts to minimize postharvest losses of rice therefore should be pursued.

5.2 Recommendations

The following recommendations are suggested:

Rice should always be stored in a well ventilated room and should also be protected during storage against insects and rodents by using appropriate insecticides.

Introduction of more efficient milling machines is more than necessary since SB-30 which gave the best results in this study yielded head grains that are uncompetitive.

This study should be repeated at different ecological zones using different rice varieties to generate more information on postharvest losses at different ecological zones and rice varieties.

Other losses such as transportation, winnowing and handling losses which were not studied in this work should be investigated.

Economic losses associated with postharvest losses of rice at various stages should also be studied and quantified.

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APPENDICES

Appendix 1: Semi Structured Survey Questionnaire

Kwame Nkrumah University of Science and Technology

College of Agriculture and Natural Resources

Department of Horticulture/ Post Harvest Physiology

A SURVEY TO DETERMINE RICE FARMERS' KNOWLEDGE AND PERCEPTION OF POST HARVEST LOSSES OF RICE FROM HARVESTING TO MILLING.

Place:……………………… Date …………………… Age ………………………..

Name of respondent:……………………………… Sex: A. Male B. Female

1. How long have you been growing rice? A. 1-4 years B. 5-9 years C. 10-14 years D 15-19 years E.20 or more years.
2. What is the area of your rice field in acres?...
3. In what topography is your rice field? A. Upland B. Lowland C. Swampy
4. What rice variety or varieties do you grow? ………………….………………

5. Do you experience post harvest losses? A. Yes B. NO

6. What causes pre harvest losses of rice according to your perception?...

7. What causes post harvest losses of rice according to your perception?..

8. At what stage do you experience the highest post harvest losses? A. Harvesting B. Threshing C. Transportation D. Winnowing E. Milling

9. In what variety/varieties do you experience the highest post harvest losses?

   ……………………………………………………..

10. Do you own any post harvest equipment or machine? A. Yes B. No

11. Do you use any post harvest equipment or machine? A. Yes B. No

12. If yes, which one/s………………………………………………………….

13. What quantity of rice do you lost during the post harvest activities? A. 0-9% B.10-19% C. 20-29% D.30-39% E.40% and above.

14. What is your perception of post harvest losses of rice in general? A. Normal B. Too much

15. What harvesting method do you use?..

16. What threshing method do you use? ……………………………………………

17. How do you dry your rice?...

18. Do you store your rice before milling? A. Yes B. No

19. Where do you mill your rice?..

20. Which type of milling machine do you use to mill your rice?..........................

21. What do you think can be done to reduce post harvest losses of rice fron harvesting to milling?..

THANK YOU!!!!!!!!!!!!!!!

Appendix 2: Field Photos

Plate 1: A GANN Electronic Moisture Content Machine used

Plate 2: A digital Scale used in Weighing Harvesting and Threshing Losses

Plate 3: Collection of Post Harvest Losses

Plate 4: Using Panicle Harvesting Method

Plate 5: Collection of Threshing Losses

Plate 6: A picture showing a bad post harvest practice of placing harvested rice in water by rice farmers at the "Nobewam" irrigation site.