SEED AND GRAIN QUALITY CHARACTERISTICS OF SOME RICE VARIETIES IN GHANA

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BY

ERIC S. TOKPAH

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DECLARATION

I declare that this thesis submitted by me for MSc. degree in Seed Science and Technology at the Kwame Nkrumah University of Science and Technology in Kumasi, Ghana, is my own independent work. References to other peoples work have been duly acknowledged and the work has not been presented elsewhere for any degree.

ERIC S. TOKPAH ------------------------------------- ------------------------------
STUDENT Signature DATE

Dr. (Mrs.) NANA S. OLYMPIO---------------------- ------------------------------
SUPERVISOR Signature DATE

Mr. P. Y ADJEI-- -----------------------------
HEAD OF DEPARTMENT Signature DATE

DEDICATION

To my father, Samson S. Tokpah, who got mysteriously missing in 1995 while seeking refuge in Guinea, I pray and hope he is well and happy where ever he is and wish that one day we’ll be together again

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ABSTRACT

Forty six rice varieties, (34 from Crop Research Institute in Kumasi, Ghana and 11 from WARDA and 1 from Ivory Coast) were evaluated for their seed and grain quality. These varieties were multiplied at the Nobewam rice multiplication center in the Ashanti Region, Ghana. Forty five days after harvesting, the seeds were tested for their milling quality, pasting characteristics and germination and vigor percentages. Grain length, length to width ratio and the thousand hulled and milled rice grain weights were also determined. Based on the thousand hulled grain weights, the varieties were categories into five ranges; 27-30grams, 30-33grams, 33-36grams, 36-39grams and above 39grams. The hulled grain length were classified into three, as very long (32), long (12) and medium (2). Based on the width, the hulled grains were also classified as semi-spherical (39 varieties). Using the data on the length and length to width ratio of the milled rice grains, the varieties were classified as extra long (33 varieties), long (12 varieties) and medium (1 variety). They were further classified base on their length to width ratio as slender (27 varieties). From the germination and vigor tests, eleven varieties had good vigor percentages (above 80%). The varieties performed differently during the milling test. Of the forty six varieties rice varieties tested for the milling performance, twenty nine varieties were categorized as grade 1 among the head rice percentage varieties. For pasting characteristics, the breakdown viscosities ranged from 0.0 BU to 71.0 BU. Based on the breakdown viscosity values, the varieties were categorized into three groups; low (≥0≤10.9BU) 29 varieties, intermediate (≥11≤19.9BU) 5 varieties and high (≥20BU) 12 varieties. The time used by the varieties to reach gelatinization temperature ranged from 17. 53 minutes to 29.18 minutes. Based on the parameters studied, 29 varieties are recommended for distribution to farmers to increase the number of varieties that farmers and consumers have to choose from.

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CHAPTER ONE

INTRODUCTION

Today, about 800 million people are suffering from malnourishment and hunger worldwide, thus creating the need for a sustainable increase in rice production to improve global food security and contribute to poverty alleviation (Badawi (2004). The role of agricultural production remains cardinal to feed the growing population of over 6 billion people, gradually increasing on a yearly basis (Traore, 2005). To meet the nutritional needs of such a large population, it would require increasing agricultural productivity through expansion of cultivated land areas, development of crops with high yield potential, vigorous protection of yields losses due to insect-pest and improving soil fertility (Traore, 2005).

It is estimated that Africa produces an average of 14.6 million tons of rough rice per year on 7.3 million hectares between 1989 and 1996 (Traore, 2005). Out of the vast available areas, West Africa has the largest planted rice area of about 4.1 million hectares. Yet, production remains at low levels. This is probably due to poor crop management techniques, lack of research and extension system, and limited utilization of productive varieties (Badawi, 2004; Anon, 2008a).

One of the major concerns in rice production has to do with seed and grain quality (Traore, 2005). While many components contribute to rice quality, the most important are cooking and eating qualities. These parameters primarily involve the physical and chemical characteristics of starch. The constituents that play important roles in cooking and eating quality are amylose content, gelatinization temperature, and gel consistency (Traore, 2005).

According to Horna *et al*. (2005) grain quality is one of the key selection criteria highly prioritized by farmers and consumers of rice and therefore farmer select rice with traits that are desirable for consumption as well as for production and sale. In the future, grain quality will be more important as very poor consumers, who depend largely on rice for their daily food, demand higher quality rice (Traore, 2005). However defining quality is very difficult since it is defined by the end user and their preferences are highly variable. For instance, in the Middle East consumers prefers long grain, well milled rice with aroma while the European community generally prefers long grain rice with no scent because the presence of any scent signals spoilage and contamination (Troare, 2005).

In West Africa, quality is associated with the type of food people prepare for eating. In Ghana, long grain and aromatic rice are used with sauces or to prepare jollof or fried rice (Takoradi, 2008). Long grain aromatic rice has the greatest demand and is the most expensive rice on the Ghanaian market. Short grain rice is used to prepare omo tuo; this is tenderly cooked rice that is molded into balls and taken with palm butter soup or ground nut paste soup. Short grain and medium grain rice are used in porridge mixed with sugar, salt and milk, while broken rice is used for fried rice in the three African countries of Senegal, Mali, and The Gambia (Anon, 1994).

There are several varieties of rice under cultivation worldwide. These are selected based primarily on the quality of their seed and grain by consumers as well as producers (Horna *et al.*, 2005). To increase local production, good quality seed must be sown (Rickman *et al.*, 2006).

Rickman *et al*. (2006) estimated that good quality seed is expected to increase yield by 5-20 % and that the extent of this increase is directly proportional to the quality of seed that is being sown. Seed quality can be considered as the summation of all factors that contribute to seed performance (Rickman *et al.*, 2006). These factors can be grouped as genetic, physical, and physiological quality. The current study examined some of the physical qualities and one aspect of the physico-chemical quality.

The aim of this research was to study seed and grain characteristics of 46 rice accessions focusing on the following:

- Determination of the seed and grain dimensions in length, width (size and shape)
- Evaluation of milling and pasting characteristics of the varieties
- Determination of germination percentage and vigor of the varieties.

While several researchers have investigated seed and grain characteristics of different varieties of rice, studies that examined those characteristics for the diversity of rice in this study were not found. The current research sought to fill that void. It is hoped that results from this investigation will be useful to farmers and the scientific community as recommended options to boost agricultural production.

CHAPTER TWO

LITERATURE REVIEW

2.1. Rice Taxonomy and Botany

Rice is the grain with the second highest worldwide production after maize (Boumas, 1985). The domesticated rice comprises two species of food crop in the Poaceae ("true grass") family: *Oryza sativa* and *Oryza glaberrima* (Linscombe, 2006). These plants are native to Tropical and Subtropical Southern Asia and Southeastern Africa, respectively (Linares, 2002).

Rice is grown as a monocarpic annual plant, although in the tropical areas it can survive as a perennial and can produce a ratoon crop and survive for up to 20 years (Boumas, 1985). It is also an important crop in subtropical and temperate zones, the yield being higher in temperate areas than in the tropics (Boumas, 1985). It can grow up to 1-1.8m tall, or more depending on the variety and soil fertility. As a member of the grass family, rice has long, slender leaves between 50-100cm long and 2-2.5cm broad. The small wind-pollinated flowers are produced in a branched arching to the pendulous inflorescence 30-50cm long. The edible part of the rice plant is the rice grain which is a caryopsis, 5-12mm long and 2-3mm thick, and which includes glumes, endosperm, and embryo (Boumas, 1985). Some varieties even have awns at the tips of the grain. The awn is sometimes very long on certain varieties, so that special machines are required to break off and remove the awns prior to the de-husking of the paddy (Belsnio, 1985).

Li (2003) described rice grain as rough rice or paddy, consisting of brown rice (or caryopsis) and the hull. Brown rice consists of the endosperm, embryo and several thin layers of differentiated tissues- the pericarp (the ovary wall), the seed coat, and the nuclellus. Li (2003) further suggested that the seed coat consisted of six layers of cells, with the aleurone layer, being the innermost. The embryo contains the embryonic leaves (plumule), enclosed by a sheath (coleoptiles), embryonic primary root (radical) unsheathed by the coleorhizae, and the joining part (mesocotyl). Rice endosperm consists mostly of starch granules in a proteinaceous matrix, together with sugar, fats, crude fibre and organic matter. Hull weight is about 20% of the total grain weight. The hull of some rice grains has the palea, lemmas, and richilla, while others have rudimentary glumes and perhaps a portion of the pedicel. The lemma is usually tough, archmenlike, sometime awned, and bigger than the palea. Grain ripening stage (15-65 days) can be subdivided into milky, dough, yellow-ripe, and maturity stages based on the texture and color of the growing grains. According to Hammermeister (2008), knowledge about grain quality starts with knowing the anatomy of a single grain, whether the grain is to be used for feed or for human consumption.

2.2. Origin of Rice and Distribution

The origin of cultivated rice is thought to be in Southwest Asia (Eastern India, Indo China and Southern China) and probably also in Africa (Boumas, 1985). The major rice growing regions are found in Asia, Latin America, and Africa, but the major exporting countries include Thailand, the United States, Vietnam, Pakistan, and India (Boumas, 1985). Nguyen, (2001) estimated that about 85% of the total rice production is for human consumption. Li, (2003) reported that rice is cultivated on all continents except Antarctica. Recent estimated by De Datta (1981) listed 112 rice growing countries Worldwide. These include all the countries in Asia and most of the countries of West and North Africa, some countries of East and Central Africa, most of the South and Central

America countries and Australia. Based on the wide distribution of rice, there are three international research centers focusing only rice.

2.3. Importance of rice

A vast majority of the people in the world consume rice. It is the second most important cereal in the world today and provides, together with wheat, a large proportion (95%) of the total nourishment of the world's population. It is the daily food for over 1.5 billion people (Boumas, 1985, Juliano, 1993). The reason for it being so popular is that it is easily digested.

Juliano (1993) found that rice is an essential food in the diet of one third of the world's population and further stated rice production and consumption is concentrated in Asia where more than 90% of the world's rice is grown and consumed. The 155 million hectares planted throughout the world produce about 596.5 million metric tons of paddy rice per year (Li, 2003). Rice, which is grown under a wide diversity of climates, soils and production systems, is subjected to many biotic and abiotic stresses that vary according to site. Consumption per capita and consumer preferences for a given rice type also vary from region to region (Juliano, 1993).

Rice is now a major staple food for millions of people in West Africa (Basorun, 2003). The author observed that currently, the annual demand for rice in the Sub-Region is estimated at over 8 million metric tonnes. Rapid population growth (estimated at 2.6% per annum), increasing urbanization and the relative ease of preservation and cooking have influenced the growing trend in rice consumption. Since the 1970s, production of rice has been expanding at the rate of 5.1% per annum, with 70% of the growth due to increased area cultivated to rice, and only 30% due to higher yields, per unit area (Anon., 2008a). Currently, an estimated 4.4 million hectares are under rice cultivation in West Africa (Somado *et al*., 2008). Total rice paddy production in the sub-region is estimated to be about 6.2 million metric tonnes (Anon., 2008b).

Unfortunately, West Africa does not produce the quantity of rice needed to meet its demand. To fill that gap, rice has to be imported. The Food and Agriculture Organization of the United Nations (FAO) estimated in 2006 that current rice imports into the sub-region have grown to more than 6 million metric tonnes per year costing over $1.5billion in scarce foreign exchange each year (Somado *et al*., 2008). This has worrying consequences for the balance of payments of these countries. Imports of this magnitude represent a major setback for broader development and poverty reduction efforts (Somado *et al.*, 2008).

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

The increase in demand for imported rice is primarily attributed to increased income, good storability and ease of cooking (Shabbir *et al*., 2008). Rice consumption increased by over 20% per year in the 1990s, with the increased demand being met by imports from the Far East and the Americas (Berisavljevic *et al.*, (2003). They indicated that imported rice, which is also perceived to be of better quality than local rice, is generally sold at higher prices. Currently, local production of rice hardly meets the annual demand of Ghana (Takoradi, 2008).

2.4. Physical Characteristics

The physical dimensions of rice kernels are of vital interest to those engaged in the rice industry (Anon., 2007). These dimensions are important in marketing and grading, in developing new rice varieties, in cleaning and grading equipment, in drying operations, and in processing. These include the seed/and grain size, shape and weight. These can be determined by careful measurement of the seed and grain of the rice kernels (Richman *et al*., 2006; Slaton *et al*., 2000).

Appearance is also another critical quality attribute for rice. Rice buyers, millers, and consumers judge the quality of the rice on the uniformity of its size and shape as well as the appearance of its overall size-shape relationship (Armstrong *et al.*, 2005). Grouping of varieties is made on the basis of sizes: long, medium or short (Belsnio, 1980). Rice of different sizes adversely affects the milling quality and yield; therefore, proper segregation of grain according to sizes is absolutely necessary to improve the milling quality of rice (Belsnio, 1980, Mahadevappa and Nandisha, 1987).

2.5. Seed Quality

Seed quality begins with selecting an appropriate rice variety to suite environmental conditions, management practices, and the end use of the rice (IRRI, 2009). The different rice varieties have different physical and chemical characteristics. It is therefore important to consider each variety's good and bad characteristics before making a decision on the choice of rice that will suite particular conditions.

Seed quality determines the value of the seed. If the quality of the seed is low, its value is low and vice versa (IRRI, 2009). Mbora *et al*. (2009) reported that seeds of the best quality will result in crops of the best quality in the field which will result to yields of the highest value.

Richman *et al*. (2006) reported that the quality of the seed was very important to farmers as it measures the potential performance of the seed under optimal conditions. Since high quality seed is free from various diseases and has better seed health, it is expected to produce healthy seedlings with no initial disease inoculums (Nguyen, 2001). A superior quality seed not only increases productivity per unit area, but it also helps produce uniform crops without any admixtures, important for obtaining high prices on the market. Nguyen (2001) reported that high quality paddy results in high milling recovery and better quality rice in the market, which translates into increased profits.

In choosing a rice variety for planting, it is important to consider the four basic characteristics (IRRI, 2009). These characteristics are seed dimension, maturity period, uniform filling and flowering. Most farmers consider the characteristics of seed dimension in choosing their variety for planting because of consumer's preference.

The use of good quality seeds of adapted and improved varieties is widely recognized as fundamental to increased crop production and productivity .According to Rickman *et al.* (2006) the use of good quality seed increases crop yields, decreases the number of seeds that need to be sown, and reduces the carryover of weeds, insects and diseases. Good quality seeds also allow farmers to attain high quality end products, minimize the cost of production by ensuring high rate of survival, fast growth, and low infection by diseases and pest. Mbora *et al.* (2009) also indicated that the use of good quality seed enables farmers to make the best use of available land and attain economic returns faster.

Rickman *et al.* (2006) reported that seeds of high quality contain minimum impurities and as such have high establishment rates in the field. The main criteria for describing seed quality include: Varietal characteristics, Seed lot characteristics, and Seed viability. IRRI (2009) found out that seed quality is influenced by the conditions under which the parent plant grows such as temperature, soil moisture, nutrient availability, light and competition during plant growth and seed maturity.

2.5.1. Germination and Vigor Test

The nature of seed germination and vigor constitutes another component for agricultural expansion and productivity. Richman *et al*. (2006) described germination test as a test that is used by farmers to quickly determine the quality of their seed lot. They further concluded the aim of germination test to be to determine the percentage of seeds that will develop in to normal seedlings under specified conditions for a specified period. ISTA (2007) reported that the results from a germination test can be used to compare the quality of the different seed lots and also to estimate the field planting value. According to ISTA, (2007) germination percentage expresses the proportion of the total number of seeds that are alive which is determined through controlled tests and actual counts of the number of seeds that germinate. Many rice varieties have a dormancy period immediately after harvest which ranges from 0-12 weeks (ISTA, 2007; Mahadevappa and Nandisha 1987, Richman *et al*., 2006). IRRI (2009) reported that storing rice under traditional open systems, their germination rate will begin to deteriorate. ISTA (2007) considered germination test as the only test farmers can conduct on seeds to determine if it is suitable for planting. By knowing the germination rate, farmers can adjust their planting rates to attain the desired plant population in the field (ISTA, 2007). Ocran *et al*. (1998)

reported that the minimum acceptable standard for germination percentage of certified seed rice in Ghana as 80% and above.

Black and Halmer (2006), defined seed germination as a process by which a seed embryo develops into a seedling. It involves the reactivation of the metabolic pathways that lead to growth and the emergence of the radicle or seed root and plumule or shoot. The emergence of the seedling above the soil surface is the final phase of germination and the beginning phase of plant growth called seedling establishment. According to Richman *et al.* (2006), normal and abnormal seedlings are counted on the tenth to determine the germination percentage. Schmidt (2000) defined normal seed as that seed which develops with all essential structures of a seedling and abnormal seed as the seed that has germinated during the test period but the seedling lacking essential structures such as cotyledons, or are discolored or infected by seed-born pathogen. It is reported by Black and Halmer (2006) that germination occurs if three conditions exist: the embryo must be alive; seed dormancy must be overcome, and the proper environmental conditions must exist for germination. An alteration of any of these conditions will have an impact on the germination process.

Willan (1987) indicated that seed vigor on the other hand provided a very good estimate of the potential field performance, and subsequently, the field planting value of a seed. Rickman *et al.* (2006) reported that though the speed of germination varies across varieties, the seed is considered to have germinated if the seeds absorb moisture and produce roots and the first leaf within 5 days. The ability of the germinating seed to continue to grow and survive determine crop establishment. Seedling vigor has therefore been defined by Lee *et al.* (1986) as a quality factor that determines the potential for rapid germination and fast seedling growth under field conditions and this potential varies in accordance with genetic and environmental backgrounds. It provides information on the planting value in a wide range of environments and storage potential of seed lots (ISTA, 2007). Accordingly, seeds with high vigor are expected to provide for early and uniform seedling stands which compete against various environmental stresses to produce good quality products. By knowing the seed vigor of a seed lot, farmers can then decide whether a seed lot is suitable for continued storage or for immediate planting.

Differences in seed and their vigor arise as a result of various factors which affect seed. Pollock and Roos (1972) explained that the causes of variation in seedling vigor are associated with maturity when harvested, post harvest handling and the growth habit of the plant. Perry (1981) also stated that seed vigor is determined by the seed and may be influenced by the environmental conditions during seed maturity, pre- and post-harvest handling and storage. Several environmental factors acting on the plant during its growth and maturation have an impact on the final product that relate to germination and vigor. A study on the effect of grain moisture on seedling vigor in rice by Oelke *et al.* (1969) reported that the speed of emergence of seedlings was faster when the crop was harvested at seed moisture contents below 20%. Peacock and Hawkins (1970) reported that cotton seeds produced in higher temperature and lower rainfall conditions resulted in poorer seedling vigor and lower yield (from an investigation on the effect of seed source on seedling vigor and other agronomic characteristics in cotton).

Maguire (1962) reported the existence of a positive relationship between seedling vigor and germination rate. Wanjura *et al.* (1969) showed that early emergence of cotton is correlated with both greater survival of seedlings and higher yield. Among the many components of vigor, speed of germination is recognized as an extremely important aspect of vigor (Boyd *et al.*, 1971). Seshu *et al.* (1988) used the rate of germination as a measure of seedling vigor in rice.

2.5.2. Seed Length and Width

The length of the hulled grain is simply a measure of the rough rice kernel in its greatest dimension while the width of the hulled grain is the measure of the rough rice kernel width in its maximum dimension. The length and width of the seed rice are variable, sometimes even within a variety, because of the variation in the length of the awn and the pedicel (IRRI, 2009). The size and shape (seed width) is a stable varietal property that can be used to identify a variety (Rickman *et al.*, 2006). Rice varieties are classified as short, medium, or long grain by rough kernel dimension ratio (Slaton *et al*, 2000). Since kernel type and dimension are of importance to the millers and processors, these characteristics are considered in the breeding of a new variety.

Vanangamudi *et al.* (1987) classified hulled grain based on their length as: Short (below 7.5mm), Medium (7.5-9mm), Long (9-10mm), or Very long (above 10mm), and the scale for the width was set as: Slender (below 2mm), Semi-long (2.0-2.4mm), Semi spherical (2.4-3.0mm) or Spherical (above 3mm).

2.5.3. Thousand (1,000) Seed weight

Another characteristic that measures varietal purity is the thousand (1,000) hulled grain weight. This characteristic is also very important in the identification of a variety. Takeda (1991) associated small seeds with low seedling vigor and difficult mechanical harvesting which is a problem in crop cultivation but small seed is favored under natural selection because it is frequently linked with large number of seeds per plant, more rapid maturity and wider geographic distribution. It has been concluded that the thousand (1,000) seed weight is a useful tool in calculating the seeding rates and harvest loses Anon (2007). Vanangamudi *et al.* (1987) grouped the rice hulled grains into the following categories based on their thousand seed weight as; below 15g, 15-18g, 18-21g, 21-24g, 24-27g, 27-30g, 30-33g, 33-36g, 36-39g and above 39g.

2.5.4. Milling Characteristics

Bergman *et al.* (2006) considered milling quality as one of the most important aspects of rice grain quality. The edible part of rice grain is enclosed in the glumes, which need to be first separated by milling. During milling, the hull is removed from the rough rice using a huller to yield brown rice. The most primitive implement for hulling is the wood mortar and pestle or a treadle or watermills, which are still used in some parts of Asia and Africa (Li, 2003).

Li (2003) described the milling process as the removal of the hull from the paddy followed by the removal of the embryo and bran layer from the brown rice through an abrasive mill to produce total rice (broken and whole kernels). Total milling yield includes the whole (head) rice and broken rice yield from total unclean rough rice (Khush *et al*., 1979). IRRI (2009) described the final step in the milling of rice as the separation of the whole (intact) kernels from the broken kernels using screens designed for use on long, medium or short varieties to produce whole grain. Mutters (1998) reported that broken grains cost less than the whole grain. Varieties that produce more broken grains produce less whole grains thereby reducing profits that should accrue from their sale. To produce good quality milled rice, good quality paddy must be used. IRRI (2009) described good quality paddy as paddy that have uniformly mature kernels; of uniform size and shape, free of fissures and empty or half filled grains, and free of contaminants such as stones and weed seeds. Many crop management factors have an impact on the quality of paddy which influenced the quality of the milled rice. Mahadevappa and Nandisha (1987) reported that cracks present in the paddy grains caused by improper drying, weathering stress during late harvesting and processing is a major factor that influences the milling quality of rice.

IRRI (2009) reported that there were three requirements for producing good quality milled rice. These requirements are; the paddy should have a moisture content range of 10-14%, and have a high purity, the rice mill should be clean and well maintained, and the mill should be operated by a skilled operator. Patindol (2000) indicated that the moisture content is a major factor affecting the milling quality of rice. If the moisture content is too low or too high, there will be a decline in the milling recovery and whole rice.

Milling of rice increases its shelf life and provides consumers with physical properties they desire. Therefore the goal of milling is to remove as much of the colored bran and germ as possible. The quantity of bran remaining on the surface of the grain after milling is defined as milling degree (IRRI, 2009).

2.5.4.1. Milling Degree

The degree of milling is a measure of the percent bran removed from the brown rice kernel. It influences the color and also the cooking behavior of rice. Un-milled brown rice absorbs water poorly and does not cook well (IRRI, 2009). The water absorption rate improves progressively up to about 25% milling degree after which, there is very little effect. Likewise, the nutrient content of rice is also strongly influenced since most micro-nutrients located largely in the peripheral layers of brown rice is removed with high degree of milling. Richman *et al*. (2006) indicated that high milling degree means that the milled rice is very white with relatively light milling. Degree of milling is influenced by the grain hardness, size and shape, depth of surface ridges, bran thickness and mill efficiency. It also affects milling recovery and influences consumer acceptance (Farooq *et al.*, 2005).

Belsnio, (1980) calculated milling degree based on the amount of bran removed from the brown rice. In the milling process, the higher milling degree indicates a smaller percentage of bran removed from the milled rice.

2.5.4.2 Milling Recovery

Milling recovery is the percentage of milled rice (total rice yield) obtained from the sample of the paddy after milling. It can be computed by dividing the weight of the milled or polished rice recovered by the weight of the paddy sample used (IRRI, 2009). Thompson *et al.* (1990) reported that the maximum total milling yield of the paddy ranged from 65% to 75%. RTWG (1997) reportedly set the standard for total milled rice recovery as premium (>70.1%), grade 1 (>65.1<70.0%), grade 2 (>60.1<65.1%) or grade 3 (>55.1<60%). For a sample to pass the milling yield test, it must be categorized in one of the above standards. During whitening, the bran layer of the brown rice is removed to improve the appearance of the rice. The removal of the bran layer does not add any nutritional value to the milled grains.

2.5.4.3. Head or Whole Rice

Milling appraisal quality is based on head rice and total rice obtained from the sample after milling (Thompson *et al.*, 1990). Head rice or head rice percentage is the weight of head grain in the rice lot. Farooq *et al.* (2005) reported that whole rice normally include broken grains that are above 75% of whole kernel. Thompson *et al.* (1990) indicated that maximum head rice yield ranges from 55% to 65%. Whole rice yield is one of the most important criteria for determining milling rice quality. According to RTWG (1997), an accession is acceptable for release in the Philippine only if its grain quality meets one of the following head rice criteria; premium (>57%), grade 1 (>48.0<56.9), grade 2 (>39.0<47.9%) or grade 3 (>30.0<38.9). The actual head rice percentage in a sample of milled rice will depend on varietal characteristics, production factors, harvesting and the drying milling process. However, harvesting, drying and milling can be responsible for some losses and damage to the grain (Farooq *et al.*, 2005). Whole rice is expressed as a percentage of the paddy rice. Mutters (1998) defined broken grains as milled rice with length less than one quarter of the average length of the kernel. He found out that broken grains normally have lower value than that of head rice.

2.6. Grain Quality

Li (2003) reported that there are more than 1,200 varieties of rice under cultivation throughout the world. Nguyen (2001) indicated that the differences in varieties were related to morphology of the plants and grains, resistance to falling, precocity, ramification, productivity, as well as resistance and tolerance to biotic and abiotic factors. According to Slaton *et al*. (2000) rice is marketed under three market types designated as long-grain, medium-grain, and short-grain. Varieties of each grain type must conform within narrow limits to the size and shape specifications established for that type. Thus, grain size and shape are among the first criteria of rice quality that breeders consider in developing new varieties for release in commercial production (Mutters, 1998). If the variety does not conform to recognized standards for grain size, shape, weight, and uniformity, it is simply not considered for release (Mutters, 1998; Anon., 2007).

In early developmental stages, close visual examination of the grain is made to ascertain that its configuration conforms to that of other commercially acceptable varieties of the same grain type. Inherent grain defects, such as irregularly shaped grains, sharp pointed extremities, oversized germs, and deep creases which cause bran streaks in milled rice, must also be eliminated in early developmental work, as these defects reduce the milling yields of rice and detract from the general appearance of the processed product (Mutters, 1998).

To the farmer, according to Juliano (1993), grain quality refers to quality of seed for planting and dry grain for consumption, with minimum moisture, microbial deterioration and spoilage. The miller or trader looks for low moisture, variety integrity and high total and head milled rice yield. Market quality is mainly determined by physical properties and variety name, whereas cooking and eating quality is determined by physico-chemical properties.

Martinez *et al.* (2005) reported that demand by consumers for rice of better quality can also influence its production. Different characteristics of 'grain quality' of rice largely determine the product's market price and acceptability. If the consumer does not like the flavor, texture, aroma, appearance or ease of cooking and processing in a new variety, whatever other outstanding traits it may possess loses its value. The quality of rice is closely related to the quality of its milled whole kernels, since all the domestic rice crop is milled to a high degree (Anon., 2007).

Hammermeister (2008), suggested that knowing about grain quality starts with knowing the anatomy of a single grain, whether the grain is to be used for feed or for human consumption, the key characteristics of a grain still apply. Research from IRRI (2009) further indicated that rice grain quality was not solely a varietal characteristic but also depended on the crop production environment, harvesting, processing and handling system.

Irshad (2001) categorized the quality characteristics in rice into 3 broad areas: (1) physical characteristics which include moisture content, shape, size, and milling (2) the analysis of physico-chemical characteristics of rice including amylose content, protein content, gel consistency, volume of expansion of cooked rice, and cooking time and (3) the organoleptic quality of cooked rice which include colour, aroma, hardness, stickiness, and consistency. For the purpose of this research, the studied seed length and width, grain length and width, thousand seed and milled grain weight and milling characteristics are all physical property of paddy and milled rice grain. The pasting property is the only physico-chemical properties studied.

2.6.1. Grain Dimension

The length and width of the rice grain are important attributes that determine the classes of rice. Rice grains may be objectively classified into grain-type categories based upon three physical qualities: length, shape, and weight. Length is a measure of milled-rice kernel in its greatest dimension. The shape is determined by a ratio of two of the three dimensions - length, width, and thickness. Richman *et al.* (2006) classified milled rice grain based on the length- width ratio as slender (> 3.0), medium (> 2.1 < 3.0), bold (> 1.1 <2.0) and round (< 1.1).

Belsnio (1980) was able to determine the grain class of rice by measuring the length of the whole grain. He classified the type of milled rice according to the length of the whole grain as: Extra long - milled rice of which 80 % of the whole milled rice kernels have a length of 7.0 mm or more, long -milled rice of which 80 % of the whole milled rice kernels have a length of 6.0 mm. or more but shorter than 7.0 mm, medium -milled rice of which 80% of the whole milled rice kernels have a length of 5.0 mm. or more but shorter than 6.0 mm, and short -milled rice of which 80 % of the whole milled rice kernels are shorter than 5.0 mm. Some attempts have been made to subdivide the types into finer gradations, such as long-slender and medium-slender. However, these distinctions may not be justified, since there is considerable overlap between long and long-slender and between medium and medium-slender types (Belsnio, 1980).

2.6.2. Thousand (1,000) Grain Weight

The 1,000 grain weight provides information about the size and density of the grain. Grain of different density mill differently, and are likely to retain moisture differently and cook differently (Richman *et al*., 2006). Uniform grain weight is important for consistent grain quality. The weight of rice kernels can vary considerably with moisture content, the type of soil where the rice is grown, fertilizer treatment, and weather conditions.

2.6.3. Pasting Characteristics

Several tests have been established to test for the functional properties of rice that are of importance to specific food processing applications (Perdon *et al*., 2001). Among these, determining pasting properties with amylograph have been widely used (Juliano, 1985).

Srzednicki *et al.* (2009) defines pasting as the phenomenon following gelatinization when starch slurry containing excess water is heated. It involves further granule swelling, additional leaching of soluble components, and eventually, especially with the application of shear, a total disruption of granules, resulting in molecules and aggregates of molecules in dispersion or solution.

When analyzing the pasting properties, the cooking behavior of starches and the viscosity of the resulting pastes are studied. The most commonly used instrument is a Bra bender Visco-amylograph (Troare, 2005). A starch suspension is cooked under a defined time, temperature and shear protocol, and its viscosity is continually recorded. The results reveal six key points, namely; the pasting temperature, peak viscosity, hot-paste viscosity, cool-paste viscosity, breakdown viscosity, setback viscosity and the time and temperature to reach these viscosities (Zobel, 1984). Limpisut *et al* (2002) explained the importance of the paste viscosity parameters on the cooking, eating and processing quality of milled rice. The authors defined the following paste viscosity parameter terms; the Pasting temperature as the temperature which indicated an initial increase in viscosity; Peak viscosity was defined as the maximum viscosity during the heating cycle; viscosity at 95°C as the Start of holding period. Hot paste viscosity indicated viscosity after 15minutes at 95°C which is referred to as the start of cooling period; Cool paste viscosity indicated viscosity at 50°C which is the end of cooling period; and Viscosity after 15 minutes at 50°C indicated the end of final holding period. The breakdown viscosity was defined by Limpisut *et al.* (2002), as the differences between the peak viscosity and the final viscosity at 95°C and the setback viscosity as the difference between the final viscosity and peak viscosity at 50°C.

Linscombe (2006) however defined hot paste viscosity as viscosity of the slurry after being heated to 95°C; cool paste viscosity as viscosity of the slurry after being heated to 95°C and uniformly cooled to 50°C. The author further concluded that lower values of hot paste indicated softer and stickier cooking types of rice, while values less than 200 for cool paste indicate softer cooking types of rice. Gayin *et al.* (2009) reported that peak viscosity, hot paste viscosity, cool paste viscosity, breakdown viscosity, setback viscosity and gelatinization temperatures ranged from 79BU-248.5BU, 70.5BU-224.5BU, 195.0BU-440BU, 0.0BU-86BU, 115BU-190.7BU and 81.2°C-86.9°C respectively. Juliano (1983) reported much higher values for these viscosities, for example peak viscosity and cool paste viscosity ranged from 765BU-940BU and 770BU-880BU respectively.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Origin of Planting Materials and Research Locations

One hundred accessions of rice collections from Ghana and the sub region of West Africa were sown in July 2009, during the major season in the rice multiplication plot in Nobewam (0 6˚38΄122″, W 001˚ 16΄54.7″, 195m above sea level), Ashanti region, Ghana. This area is characterized by double maximum rainfall lasting from March to July and again from September and normally ends in the latter part of November with mean annual rainfall of 1200mm which is ideal for the minor cropping season (Anon, 2002).

The soils at the experimental site were sampled to a depth of 20cm at three different spots and analyzed to determine the nutrients available in the soil. The soil analysis was carried out at the Department of Soil Science laboratory, Kwame Nkrumah University of Science and Technology (KNUST). Three basic methods were used to determine the nutrients concentration in a soil sample. The method developed by Walkley and Black (1934) was used to determine the organic carbon concentration, Kjeldahl method developed by Bremmer (1965) in determining the nitrogen concentration and the Bray method developed by Bray and Kurtz (1945) to determine the phosphorus concentration.

The field was laid out using a randomized complete block design (RCBD). Hundred varieties were replicated three times with each variety been sown in a plot size of 1.5m x 2.5m with spacing of 20cm x 20cm. The total area covered by the 300 small plots was 2,040m^2.

Weeds were control using weed control chemical at the initial stage follow by two times of hand weeding prior to flowering. Out of the 100 varieties, forty-six; 1 (one) variety from the Ivory Coast, 11 (eleven) varieties from WARDA and 34 (thirty-four) varieties from Crops Research Institute (CRI), Ghana, were used for data collection on their seed and grain characteristics.

Table 1: Varieties of Rice and their Sources

Varieties	Source	Varieties	Source
ARCCU3Fa7-L14P8-B-B-1(17)	Africa Rice	ARCCU3Fa9-L6P5-B-B-2(18)	Africa Rice
ARCCU2Fa9-L3P3-B-B-4(23)	Africa Rice	ARCCU3Fa7-L3P3-B-B-1(27)	Africa Rice
ARCCU3Fa3L7P1-B-B-1(34)	Africa Rice	ARCCU12Fa1L6P7-24-1-1-2(36)	Africa Rice
ARCCU3Fa12L8P1-B-B-1(39)	Africa Rice	ARCCU3Fa9L6P1-B-B-1(41)	Africa Rice
N12	Africa Rice	N15	Africa Rice
CRI-4(61)	CRI, Ghana	CRI-5(62)	CRI, Ghana
CRI-7(64)	CRI, Ghana	CRI-8(65)	CRI, Ghana
CRI-9(66)	CRI, Ghana	CRI-11(68)	CRI, Ghana
CRI-16(73)	CRI, Ghana	CRI-19(76)	CRI, Ghana
CRI-20(77)	CRI, Ghana	CRI-21(78)	CRI, Ghana
CRI-22(79)	CRI, Ghana	CRI-26(83)	CRI, Ghana
CRI-33(90)	CRI, Ghana	CRI-34(91)	CRI, Ghana
CRI-34(91)	CRI, Ghana	CRI-35(92)	CRI, Ghana
CRI-37(94)	CRI, Ghana	CRI-38(95)	CRI, Ghana
CRI-40(97)	CRI, Ghana	CRI-41(98)	CRI, Ghana
CRI-42(99)	CRI, Ghana	CRI-43(100)	CRI, Ghana
CRI-44(101)	CRI, Ghana	CRI-45(102)	CRI, Ghana
CRI-46(103)	CRI, Ghana	CRI-48(105)	CRI, Ghana
CRI-50(107)	CRI, Ghana	CRI-51(108)	CRI, Ghana
CRI-62(119)	CRI, Ghana	CRI-71(128)	CRI, Ghana
CRI-74(131)	CRI, Ghana	CRI-75(132)	CRI, Ghana
IDSA85(133)	Ivory Coast		

The panicles were hand harvested and manually threshed to obtain the paddy. Seeds were dried in the sun to 14% and below moisture content, put in sacks and stored under room temperature for 45 days before determining seed and grain dimensions (length, width and shape), milling and pasting characteristics, germination and vigor percentages.

3.2. Data collected

3.2.1. Seed Length and Width

To obtain the seed length and width, 20 hulled grains were counted at random from the sample and measured at the respective greatest dimensions using a vernier caliper (Rickman *et al.*, 2006). The average of the 20 measurements was recorded. The scale by Vanangamudi *et al.* (1987) was used to classify seed length as: Short (below 7.5mm), Medium (7.5-9mm), long (9-10mm), Very long (above 10mm) and seed width as Slender (below 2mm), Semi long (2-2.4mm), Semi spherical (2.4-3mm), and Spherical (above 3mm).

3.2.2. Thousand (1,000) Hulled Grain Weight

To obtain the 1,000 hulled grain weights, eight replicates of 100 hulled grains were counted at random from the samples and weighed using a scale (METTLER PM 400) at the Soil Science Laboratory at KNUST (Kwame Nkrumah University of Science and Technology). The average of the eight replicates was multiplied by 10 to obtain the 1,000 hulled grain weights (CFS, 2007; Willan, 1987). The varieties were grouped into five groups as 27-30grams, 30-33grams, 33-36grams, and 36-39grams and above 39grams based on the hulled grain weights obtained.

3.2.3. Milled Grain Length and Length to Width Ratio

The dimensions of the grain (milled rice) were measured using a venier caliper. Twenty grains of each variety were selected at random from the sample and measured to determine their length and width (Rickman *et al.*, 2006). The average of the length and width was recorded as their length and width. Based on the length of the grains, the milled rice grains were classified into four classes; extra long (>7.5mm), long (>6.6 <7.49mm), medium (>5.51 <6.6) and short (<5.5mm) (Rickman *et al.*, 2006). The milled rice grains were again classified into four classes considering their length to width ratio as slender (>3), medium (>2.1 <3), bold (>1.1 <2) and round (<1.1).

3.2.4. Seed Germination and Vigor

Germination and vigor tests were conducted using sand as the growing medium in accordance with ISTA (2007) procedure. One hundred seeds replicated four times per variety were sown in two trays after 45 days of storage at room temperature. First and final counts were done on the fifth and tenth day respectively after seed sowing. The first count was considered as the vigor (ISTA, 2007) (Plate 1). Both normal and abnormal seedlings were examined and counted during the inspection on the tenth day (Plate 2) to determine the germination percentage (Rickman *et al.*, 2006).

Plate1: Seedling inspection on the fifth day to determine vigor

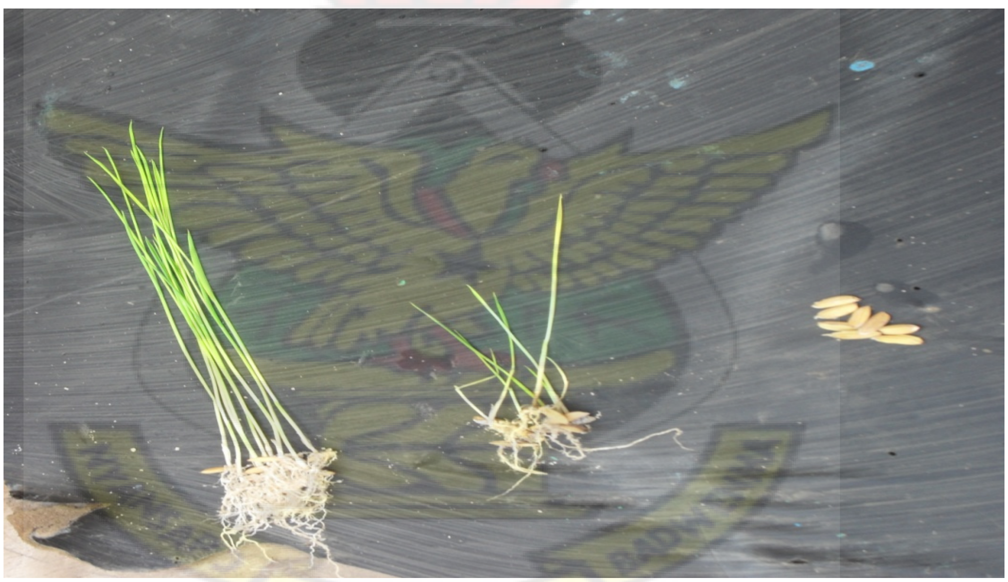

Plate 2: Normal seedlings, abnormal seedlings and un-germinated seeds during inspection on the 10th day to determine germination percentage.

3.2.5. Thousand (1,000) Milled Grain Weight

Eight replicates each of 100 milled rice grains were randomly counted and each sample was weighed in grams based on the CFS (2007) procedures. The average weight was calculated from the eight weights of 100-grains replicates. The mean was multiplied by 10 to determine the thousand (1,000) grain weight of each variety. The varieties were grouped into five ranges as 21-24grams, 24-27grams, 27-30grams, 30-33grams and 33-36grams based on the milled grain weights obtained.

3.2.6. Milling Characteristics

Milling was done at the Irrigation Development Authority laboratory in Ashiaman, Greater Accra Region, Ghana. The moisture content of the various samples was determined using the Riceter moisture meter before milling. Five hundred grams of the paddy rice were de-husked using a Satake testing husker. Brown rice was obtained after dehusking. The Satake abrasive whitener with whiteness set mid way between low and middle and timer at 15 minutes was used to polish the brown rice to obtain the white rice (milling yield). A cyclone Satake (50Hz) rice grader was used to separate the broken grains (grains less than ¼ of the average length) from the head rice. This process produced the weight of whole grain or head rice. The weights obtained were recorded after each operation. The weights were used to determine the milling characteristics of the various rice samples. The following equations were used to determine the milling characteristics of the various rice samples (IRRI, 2009):

$$\%\ \text{Milling Degree} = \frac{\text{WtofMilledRice}}{\text{WtofBrownRice}} \times 100$$

$$\%\ \text{Milling Recovery} = \frac{\text{WtofMilledRice}}{\text{WtofSampleused}} \times 100$$

$$\% \text{ Head Rice} = \frac{\text{WtofWholeGrains}}{\text{WtofSampleused}} \times 100$$

3.2.7. Pasting Characteristics

The pasting properties of the grains of the various rice accessions were taken at the Food Research Institute, Greater Accra Region, Ghana, using the Bra bender Viscograph. About 50grams of rice grains were ground into flour. Forty grams of the flour were mixed with 420ml of distilled de-ionized water. The content was heated from 50 to 95°C at a rate of 1.5°C/min, held at 95°C for 15 minutes, and cooled to 50°C at 1.5°C/min and finally held at 50°C for 15 minutes. The pasting properties were measured using the Bra bender Viscograph. From the curve provided by the Bra bender Viscograph; the Peak, hot paste, and cool paste viscosities of the pastes were measured and used to determine the breakdown and setback viscosities. To obtain the breakdown viscosity, you minus the hot paste viscosity value from the peak viscosity value and for the setback viscosity, you minus the hot paste value from the cool paste viscosity value to obtain its value. Gelatinization temperatures were also measured for each accession.

3.3. Statistical Analysis

Data collected were analyzed using GenStat statistical package to generate analysis of variance (ANOVA) and means separated by Tukey's and LSD at 5%. The Tukey's was used to separate means greater than or equal to 6 and LSD was used to separate means that were 1 or more but less than 5.

CHAPTER FOUR

RESULTS

Soil Analysis

The results of the soil analysis of the experimental site are presented in Table 2. The nitrogen, phosphorus and potassium concentrations are evenly distributed on the experimental site. The experimental site had a soil pH that ranged from 6.08 – 6.27; the exchangeable cat-ion ranged from 8.1 – 10.71; organic matter content that from 2.00 – 2.62 and total nitrogen from 0.25 – 0.27.

Table 2: Soil samples analyzed from the experimental site

Parameter	**Site 1**	**Site 2**	**Site 3**
pH(1-2.5 H_20)	6.27	6.08	6.11
Organic C (%)	1.16	1.52	1.46
Organic matter (%)	2	2.62	2.52
Total N (%)	0.25	0.25	0.27
Available P (mg/kg)	23.88	27.37	38.4
Exchangable cat-ion (cmol/kg)			
Ca	3.2	3.2	3
Mg	4	4.8	3.8
K	0.1	0.21	0.09
Na	0.17	0.18	0.21
Al	0.5	1.3	0.6
H	0.7	1	0.4
ECE (cmol/kg)	8.87	10.71	8.1
Particle size distribution			
% Sand	54	46	50
% Clay	24	24	22
% Silt	22	30	28

With the results from the analysis, basal application were administered to the field with 18.6 kg/ha of NPK (15-15-15) follow by the application of 9.9 kg/ha of Urea at tillering and 12.9 kg/ha during panicle initiation.

Seed Length and Width

The results of the length and width of the hulled grain are presented in (Tables 3a and 3b). Based on the scale by Vanangamudi *et al* (1987), the length of the hulled grain were categorized into three groups, very long (32 varieties), long (12 varieties) and medium (2 varieties). CRI-41 (12.8mm), CRI-19 (12.7mm) and CRI-46 (12.6mm) which had the longest length were significantly (p=0.05) different from ARCCU3Fa7-L14P8-B-B-1 (10.2mm), CRI-75 (10.2mm), CRI-71 (10.1mm) and CRI-26 (10.0mm) which had the shortest length in the very long hulled grain varieties. ARCCU3Fa9-L6P5-B-B-2 (9.9mm) was significantly different from CRI-21 (9.2mm), ARCCU12Fa1L6P7-24-1-1-2 (9.1mm) and CRI-11 (9.1mm) in the long hulled grain varieties. These were significantly different from the rest of the varieties in their various groups. However, there was no significant difference among the medium hulled grain varieties (Table 3a). The widest seed width (3.2mm) was found in ARCCU3Fa9-L6P5-B-B-2 followed by ARCCU3Fa12L8P1-B-B-1 (3.1mm) (Table 3b). The shortest length and the thinnest width were found in CRI-43 and CRI-4. The varieties were also grouped into three groups based on their width to determine their shape as spherical (4 varieties), semi-spherical (39 varieties) and semi long (3 varieties) (Table 3b). ARCCU3Fa9-L6P1-B-B-1 (2.967mm) and CRI-43 (2.967mm) were significantly (p=0.05) different from the six last varieties (CRI-41, CRI-37, CRI-19, CRI-5, IDSA85 and CRI-54) in the semi spherical varieties (Table 3b). No significant difference was however observed among the spherical and semi long hulled grain (Table 3b).

Table 3a: Varieties grouped as very long, long and medium based on the hulled grain length.

VERY LONG

Varieties	Length(mm)
CRI-41	12.8a
CRI-19	12.7a
CRI-46	12.7a
ISDA85	12.5ab
CRI-34	12.4abc
CRI-44	12.2abcd
CRI-38	12.1abcde
CRI-42	11.9bcdef
CRI-33	11.9bcdef
CRI-1	11.7cdefg
CRI-37	11.6defgh
CRI-58	11.6defgh
CRI-35	11.5defgh
CDU2	11.4efgh
CRI-62	11.4efgh
CRI-5	11.4fgh
CRI-16	11.3fghi
CRI-9	11.3fghi
CRI-20	11.2ghi
CRI-40	11.1ghi
CRI-48	11.1ghi
CRI-74	11.0ghij
CRI-45	11.0ghij
CRI-7	10.9hijk
CRI-4	10.9hijk
CRI-51	10.6ijkl
CRI-54	10.4jkl
CRI-22	10.3jkl
N15	10.3kl
ARCCU3Fa7-L14P8-B-B-1	10.2l
CRI-75	10.2l
CRI-71	10.1l
CRI-26	10.0l

LONG

Varieties	Length(mm)
ARCCU3Fa9-L6P5-B-B-2	9.9a
N12	9.8ab
ARCCU3Fa7-L3P3-B-B-1	9.8ab
CRI-50	9.8ab
ARCCU2Fa9-L3P3-B-B-4	9.7abc
ARCCUFa3L7P1-B-B-1	9.7abc
CRI-8	9.4abc
ARCCU3Fa12L8P1-B-B-1	9.2abc
CRI-21	9.2bc
ARCCU12Fa1L6P7-24-1-1-2	9.1c
CRI-11	9.1c

MEDIUM

Varieties	Length(mm)
ARCCU3Fa9L6P1-B-B-1	8.6
CRI-43	8.2
LSD 5%	0.774

Table 3b: Varieties grouped as semi spherical based on the hulled grain width to determine their shape.

SEMI SPHERICAL	
Varieties	Width(mm)
ARCCU3Fa9-L6P1-B-B-1	2.967a
CRI-43	2.967a
N12	2.933ab
ARCCU3Fa7-14P8-B-B-1	2.933ab
CRI-45	2.933ab
CRI-11	2.867abc
ARCCU2Fa9-L3P3-B-B-4	2.867abc
N15	2.833abcd
CRI-40	2.833abcd
CRI-9	2.8abcde
CRI-48	2.8abcde
CRI-35	2.767abcde
CRI-21	2.767abcde
CRI-20	2.767abcde
CRI-16	2.767abcde
CRI-71	2.767abcde
CRI-38	2.733abcde
CRI-26	2.733abcde
ARCCUFa3L7P1-B-B-1	2.733abcde
CRI-75	2.733abcde
CRI-50	2.733abcde
CRI-46	2.733abcde
CRI-40	2.7abcde
CRI-8	2.7abcde
CRI-1	2.7abcde
CRI-22	2.667bcde
CRI-62	2.667bcde
CRI-58	2.667bcde
CRI-51	2.667bcde
ARCCU12Fa1L6P7-24-1-1-2	2.667bcde
CRI-44	2.667bcde
CDU2	2.6cde
CRI-7	2.567de
CRI-41	2.533e
CRI-37	2.533e
CRI-19	2.533e
CRI-5	2.533e
ISDA	2.533e
CRI-54	2.533e

Grain Length and Length to Width Ratio

The results of the milled grain length and length to width ratio are shown in Table 4a and 4b. The longest grain length (9.4mm) was found in CRI-41 followed by 9.3mm for CRI-46 (Table 4a). Based on the scale by Richman et al, (2006), the varieties were grouped into three based on the milled grain length as extra long (33 varieties), long (12 varieties) and medium (1 variety; CRI-43) (Table 4a). CRI-41 was significantly different from ARCCU3Fa9-L6P5-B-B-2 (7.5mm) in the extra long grain varieties. CRI-71 (7.4mm) was significant difference from ARCCU3Fa9L6P1-B-B-1 (6.833mm) in the milled long grain varieties. Significant differences were also found among the various varieties in their different groups. The largest length-width ratio (4.1) was found in CRI-41 followed by CRI-34 and CRI-46 (4) and the smallest was found in CRI-43 (2.4). The varieties were also grouped in two based on the length to width ratio as slender (27 varieties) and medium (19 varieties) (Table 4b). CRI-41 (4.1) was significantly ($p = 0.05$) difference from CRI-40 (3.1) in the slender varieties but no significant difference was observed in the medium milled grain varieties (Table 4b).

Table 4a: Varieties grouped as extra long, long and medium based on their milled grain length.

EXTRA LONG		LONG	
Varieties	Length(mm)	Varieties	Length(mm)
CRI-41	9.4a	CRI-71	7.4a
CRI-46	9.333ab	CRI-50	7.367ab
CRI-19	9.133abc	CRI-8	7.33ab
CRI-44	9.133abc	ARCCU2Fa9-L3P3-B-B-4	7.3ab
CRI-9	9abc	ARCCU12Fa1L6P7-24-1-1-2	7.267ab
CRI-38	8.933abcd	CRI-75	7.233ab
CRI-34	8.933abcd	ARCCUFa3L7P1-B-B-1	7.233ab
CRI-62	8.933abcd	CRI-21	7.133ab
CRI-42	8.9abcd	ARCCU3Fa7-L3P3-B-B-1	7.133ab
IDSA85	8.833abcd	CRI-11	7.033ab
CRI-33	8.7abcde	ARCCU3Fa12L8P1-B-B1	6.867ab
CRI-4	8.7abcde	ARCCU3Fa9L6P1-B-B-1	6.833b
CRI-35	8.633bcdef		
CRI-1	8.633bcdef		
CRI-37	8.6cdefg		
CRI-5	8.6cdefg		
CRI-58	8.6cdefg		
CRI-16	8.567cdefgh		
CRI-45	8.533cdefgh		
CDU2	8.467cdefghi		
CRI-40	8.433cdefghij		
CRI-48	8.433cdefghij		
CRI-7	8.233defghijk		
CRI-74	8.233defghijk		
CRI-51	8.1efghijkl		
CRI-20	7.933fghijkl		
CRI-22	7.9ghijkl		
CRI-54	7.867hjkl		
N15	7.8ijkl		
ARCCU3Fa7-L14P8-B-B-1	7.733jkl		
N12	7.633kl		
CRI-26	7.533kl		
ARCCU3Fa9-L6P5-B-B-2	7.5l		

Table 4b: Varieties grouped as slender and medium based on their milled grain length to width ratio.

SLENDER	
Variety	Ratio
CRI-41	4.1a
CRI-34	4ab
CRI-46	4ab
CRI-4	3.9abc
CRI-33	3.8abcd
CRI-44	3.8abcd
CRI-37	3.7abcd
CRI-19	3.7abcd
CRI-9	3.7abcd
CRI-5	3.7abcd
IDSA85	3.7abcd
CRI-62	3.7abcd
CRI-58	3.7abcd
CRI-42	3.6abcd
CRI-38	3.6abcd
CRI-20	3.6abcd
CRI-1	3.6abcd
CDU2	3.5abcd
CRI-22	3.4abcd
CRI-16	3.4abcd
CRI-7	3.4abcd
CRI-54	3.4abcd
CRI-51	3.4abcd
CRI-35	3.3bcd
CRI-45	3.3bcd
CRI-48	3.2cd
CRI-40	3.1d

Germination and Vigor Tests

Results from germination and vigor tests are reported in Table 5a and 5b. The highest germination (95%) was obtained in CRI-44 followed by (89%) in varieties CRI-11, CRI-21 and CRI-40 and the lowest (63%) was found in CRI-75 (Table 5a). The varieties were grouped into two groups based on the standard set by Ocran *et al* (1998) as; ≥80% (34 varieties) and ≤79.9% (12 varieties) (Table 5a). CRI-44 (94%) was significantly (p=0.05) different from CRI-8 (80%) in the greater than or equal to 80% varieties. Significant differences were also found among the means of the less than or equal to 79.9% varieties (Table 5a). The highest percent vigor (86%) was found in CRI-71 followed by (84%) in CRI-40 and CRI-44 and the lowest (54%) was found in ARCCU3Fa7-L14P8-B-B-1 (Table 5b). From the statistical analysis, it was found that CRI-71 (86%) was significantly different from IDSA85 (70%) among the greater than or equal to 70% varieties whilst no significant difference was found among the less than or equal to 69.9% varieties (Table 5b).

Table 5a: Varieties grouped as ≥ 80% and ≤79.9% based on the germination percentage.

≥ 80%		**≤ 79.9%**	
Varieties	% Germination	Varieties	% Germination
CRI-44	94a	CRI-54	79.33a
CRI-21	89.33ab	ARCCU3Fa9-L6P5-B-B-2	79ab
CRI-11	89.33ab	CRI-48	78.33ab
CRI-40	89ab	CRI-4	77.67ab
CRI-71	88.33abc	ARCCU12Fa1L6P7-24-1-1-2	77.33ab
ARCCU3Fa12L8P1-B-B-1	88abc	ARCCU3Fa9-L6P1-B-B-1	76.33ab
ARCCU3Fa3L7P1-B-B-1	88abc	CRI-43	75.33ab
ARCCU3Fa7-L3P3-B-B-1	87.67abc	CRI-5	74ab
CRI-41	87.33abcd	ARCCU3Fa7-L14P8-B-B-1	74ab
CRI-7	87.33abcd	CRI-22	73ab
CRI-35	87abcd	CRI-38	69.33bc
CRI-51	87abcd	CRI-75	63c
CRI-74	86bcd		
N15	85.67bcd		
CRI-62	85.33bcd		
CRI-19	85bcd		
CRI-50	85bcd		
CRI-33	84.33bcde		
CRI-46	84.33bcd		
CRI-42	84bcd		
CRI-34	84bcd		
CRI-26	84bcd		
CRI-9	83.67bcd		
CRI-1	83.33bcd		
CRI-58	83.33bcd		
CDU2	83.33bcd		
N12	82.33bcd		
CRI-16	82.33bcd		
CRI-45	82.33bcd		
CRI-20	82bcd		
ARCCU2Fa9-L3P3-B-B-4	82bcd		
CRI-37	81cd		
IDSA85	80.67cd		
CRI-8	80d		

Table 5b: Varieties grouped as ≥70% and ≤69.9% based on the vigor percentage.

VIGOR %	
≥ 70%	
Varieties	Means
CRI-71	85.33a
CRI-44	84.33ab
CRI-40	84abc
CRI-35	83.33abc
CRI-21	82.33abc
N15	81.33abcd
CRI-9	81.33abcde
CRI-1	81.33abcde
CRI-51	81.33abcde
ARCCU3Fa12L8P1-B-B-1	81abcde
CRI-7	80.67abcdef
CRI-58	79.67abcdefg
CRI-50	79abcdefg
CDU2	78.33abcdefgh
CRI-26	78.33ABCDEfgh
CRI-74	78.33Abcdefgh
CRI-62	78.33Abcdefgh
CRI-46	78.33abcdefgh
N12	77.33abcdefgh
ARCCU3Fa7-L3P3-B-B-1	77.33abcdefgh
CRI-16	76.33bcdefgh
ARCCU3Fa3L7P1-B-B-1	76.33bcdefgh
CRI-37	76bcdefgh
CRI-41	75.67bcdefgh
CRI-45	75.67bcdefgh
CRI-19	75.33cdefgh
ARCCU2Fa9-L3P3-B-B-1	75.33cdefgh
CRI-54	74.33defgh
CRI-11	74defgh
CRI-8	74defgh
CRI-33	73.33efgh
CRI-20	73efgh
CRI-42	72fgh
CRI-34	71.33gh
IDSA85	70h

Thousand Seed Weight and Grain Weight

The results obtained from the thousand seed and grain weights are reported in Table 6a and 6b. The thousand weight of the rice hulled varied from 27.2 grams to 44.4 grams (Table 6a). The highest seed weight was found in CRI-74 and the variety with the lowest was found in CRI-7 (Table 6a). The varieties were grouped into 5 according to their thousand seed weight ranges; from 27-30grams (6 varieties), 30-33grams (9 varieties), 33-36grams (6 varieties) and 36-39grams (8 varieties) and above 39grams (17 varieties) (Table 5a). Significant differences were found among the varieties in the thousand hulled grain weights in the various groupings based on their weights Table 6a). The thousand milled grain weight ranged from 22.6 grams to 33.4 grams. The highest grain weight was found in CRI-74 and the variety with the lowest weight was found in CRI-7 (Table 6b). The varieties were also grouped into 5 according to their thousand grain weight ranges; from 21-24grams (4 varieties), 24-27grams (14 varieties), 27-30grams (15 varieties), 30-33grams (12 varieties) and 33-36grams (1 variety; CRI-74) (Table 6b). Significant differences were also found among the varieties in the thousand milled grain weights in the various groupings (Table 6b).

Table 6a: Varieties grouped based on the thousand seed weight.

27-30g

Varieties	Weights (g)
CRI-54	29.6a
CRI-8	29.53a
CRI-11	29ab
CRI-21	28.43bc
ARCCU12Fa1L6P7-24-1-1-2	27.8cd
CRI-7	27.2d

30-33g

Varieties	Weights (g)
CRI-58	31.83a
ARCCUFa3L7P1-B-B-1	31.63ab
ARCCU2Fa9-L3P3-B-B-4	31.6ab
CRI-43	31.4ab
CRI-75	31abc
CRI-71	30.767bc
CRI-50	30.2c
CRI-26	30.1c

33-36g

Varieties	Weights (g)
CRI-4	35.43a
CRI-33	35.2ab
N15	34.33bc
ARCCU3Fa9L6P1-B-B-1	34.23bcd
CRI-5	34.07cd
ARCCU3Fa12L8P1-B-B-1	33.27d

36-39g

Varieties	Weights (g)
CRI-48	38.5a
ARCCU3Fa9-L6P5-B-B-2	38.4a
CRI-41	37.8ab
ISDA85	36.73bc
CRI-40	36.73bc
CRI-22	36.37bc
CRI-37	36.1c
ARCCU3Fa7-L14P8-B-B-1	36.1c

above 39g

Varieties	Weights (g)
CRI-74	44.4a
CRI-45	43.67a
CDU2	41.33b
CRI-62	41.3b
CRI-9	41.17bc
N12	40.77bcd
CRI-38	40.63bcd
CRI-1	40.63bcd
CRI-19	40.53bcd
CRI-16	40.13bcd
CRI-35	40.1bcd
CRI-51	39.67bcd
CRI-20	39.63bcd
CRI-44	39.5cd
CRI-46	39.33d
ARCCU3Fa7-L3P3-B-B-1	39.27d
CRI-42	39.17d
CRI-34	39.1d

Table 6b: Varieties grouped based on the thousand milled grain weight.

21-24g

Varieties	Weights (g)
CRI-11	23.3
ARCCU12Fa1L6P7-24-1-1-2	23.267
CRI-54	22.667
CRI-7	22.6
LSD 5%	0.4861

24-27g

Varieties	Weights (g)
CRI-4	26.767a
CRI-5	26.7ab
N15	26.67ab
ARCCU3Fa12L8P1-B-B-1	26.6abc
ARCCU2Fa9-L3P3-B-B-4	26.5abc
ARCCU3Fa9L6P1-B-B-1	26.07bc
CRI-75	25.97c
CRI-71	24.87d
CRI-26	24.8de
CRI-21	24.7de
ARCCUFa3L7P1-B-B-1	24.67de
CRI-8	24.43de
CRI-50	24.3de
CRI-43	24.17e

27-30g

Varieties	Weights (g)
ARCCU3Fa7-L3P3-B-B-1	29.5a
CRI-1	29.47a
ARCCU3Fa9-L14P8-B-B-1	29.23ab
CRI-46	29.23ab
CRI-19	29.13abc
CRI-33	28.67abcd
CRI-51	28.67abcd
CRI-20	28.53bcd
CRI-40	28.5bcd
CRI-58	28.47bcd
ISDA85	28.23d
CRI-34	28d
CR1-37	27.97de
CRI-22	27.1e

30-33g

Varieties	Weights (g)
CRI-45	33a
CRI-48	32.93ab
N12	32abc
CRI-9	31.93bc
CRI-62	31.73c
CRI-42	31.6cd
ARCCU3Fa9-L6P5-B-B-2	31.3cd
CRI-16	30.7cde
CRI-41	30.2de
CRI-44	30.1e
CRI-35	30.07e
CDU2	30.03e

Milling Characteristics

The highest milling recovery (70.8%) was obtained in ARCCU2Fa9-L3P3-B-B-1 and the lowest (37.3%) was found in CRI-54. No significant difference was found among the varieties in the various grouping in the percent milling recovery. The highest whole rice yield (60.1%) was found in CRI-16 and the lowest (38.8%) was found in CRI-43 (Table 7). The varieties were also grouped into four groups based on their % head rice as, premium (5 varieties: ARCCU2Fa9-L3P3-B-B-4, CRI-16, CRI-35, CRI-44 and CRI-50), grade 1 (29 varieties), grade 2 (7 varieties) and grade 3 (1 variety: CRI-43) (Table 7). The statistical analysis shows no significant difference among the premium, Grade 2 and Grade 3 varieties whilst significant ($p=0.05$) differences were found among the Grade 1 varieties (Table 7).

Table 7: Varieties grouped as grade 1 based on the head rice percentage.

GRADE 1	
Varieties	Means
CDU2	56.4a
CRI-74	56.1ab
CRI-33	56ab
CRI-45	55.3abc
CRI-19	55.2abc
CRI-48	53.9abcd
CRI-5	53.8abcd
CRI-46	53.1abcde
CRI-40	53abcde
CRI-62	52.2abcdef
CRI-20	52abcdef
CRI-75	52abcdef
N12	51.9bcdef
CRI-58	51.3cdef
IDSA85	51.2cdef
CRI-8	51cdef
N15	50.9cdef
CRI-42	50.9cdef
CRI-37	50.9cdef
CRI-51	50.9cdef
ARCCU3Fa9-L6P5-B-B-2	50.7def
CRI-38	50.5def
CRI-41	50.2def
ARCCU3Fa7-L3P3-B-B-1	50def
CRI-1	49.9def
CRI-71	49.2ef
CRI-4	48.9ef
CRI-22	48.2f
ARCCU3Fa12L8P1-B-B-1	48.1f

Pasting Characteristics

The highest peak viscosity was found in rice variety CRI-74 (201BU), followed by ARCCU3Fa12L8P1-B-B-1 (194BU) and N15 (184.5BU) and the lowest peak viscosity value (46BU) were found in CRI-5 (Appendix 1). The highest hot paste viscosity was found in rice variety ARCCU3Fa7-L3P3-B-B-1 (149BU) and the lowest was found in CRI-5 (46BU) (Appendix 1). The cool paste viscosity ranges from 380.5BU to 136.5BU and was found to be higher in ARCCU3Fa7-L3P3-B-B-1 followed by ARCCU3Fa12L8P1-B-B-1 with the lowest in rice variety CRI-5 (Appendix 1). The breakdown viscosity ranged from 0 BU to 71 BU (Table 8). The varieties were grouped into three ranges; ≥ 0≤10.9BU (29 varieties), ≥11≤19.9BU (5 varieties) and ≥20BU (12 varieties) based on their breakdown viscosity (Table 8). Significant differences were found among the 0-10.9BU, 11-19.9BU and above 20 BU varieties based on their breakdown viscosity. The setback viscosity ranged from 231 BU to 90.5 BU with the highest in ARCCU3Fa7-L3P3-B-B-1 and the lowest in CRI-5 (Appendix 1).

The longest time (29.18min) to reach gelatinization temperature was observed in variety ARCCU2Fa9-LP3-B-B-4 followed by (26.18min) in CRI-5 and the lowest time (17.53min) was observed in CRI-43 followed by CRI-7 (18.50min) (Appendix 1).

Table 8: Varieties grouped in ranges as ≥ 0≤10.9BU, ≥11≤19.9BU and ≥20BU based on the breakdown viscosity.

0-10.9BU

Varieties	Means(BU)
CRI-7	9.33a
CRI-21	2b
CRI-22	1b
CRI-8	1b
ISDA85	1b
CRI-50	1b
CRI-37	0.667b
CRI-35	0.667b
CRI-20	0.667b
CRI-1	0.667b
CRI-71	0.667b
CRI-62	0.667b
CRI-51	0.667b
CRI-9	0.333b
CRI-4	0.333b
ARCCU12Fa1L6P7-24-1-1-2	0.333b
CDU2	0.000b
CRI-42	0.000b
CRI-41	0.000b
CRI-38	0.000b
CRI-34	0.000b
CRI-33	0.000b
CRI-19	0.000b
CRI-5	0.000b
CRI-58	0.000b
CRI-54	0.000b
CRI-48	0.000b
CRI-46	0.000b
CRI-45	0.000b

11-19.9BU

Varieties	Means(BU)
ARCCU2Fa9-L3P3-B-B-4	19
ARCCU3Fa9-L6P5-B-B-2	14
CRI-43	13.5
CRI-16	12.5
CRI-44	11.5
LSD 5%	0.4861

above 20BU

Varieties	Means(BU)
CRI-74	71a
ARCCU3Fa12L8P1-B-B-1	62.5ab
ARCCUFa3L7P1-B-B-1	50.5abc
N12	50.5abc
CRI-40	41.5bcd
CRI-11	37cd
N15	36.5cd
CRI-75	36cd
CRI-26	30.5cd
ARCCU3Fa9L6P1-B-B-1	30cd
ARCCU3Fa7-L3P3-B-B-1	29.5cd
ARCCU3Fa7-L14P8-B-B-1	20d

CHAPTER FIVE

DISCUSSIONS

Soil Analysis

Based on the standard set by FAO, (2008), the soil at the experimental site had a low exchangeable cat-ion (Ca, Mg, K, Na, Al and H) concentration with high nitrogen percentage. The soil was slightly acidic based on the pH measured (FAO, 2008).

Seed Length and Width

The varieties were categorized into three groups based on their length as; very long (>10mm) 32 varieties, long (≥9≤9.9mm) 12 varieties and medium (≥7.5≤8.9mm) 2 varieties. The hulled grains were again classified base on their width as semi spherical (≥2.4<3.0mm) 39 varieties, spherical (≥3.0mm) 4 varieties and semi long (<2.0mm) 3 varieties. Vanangamudi *et al*. (1987) and Belsnio (1980) also grouped hulled grain into categories based on their length and width. Rickman *et al*. (2006) reported that size and shape were stable varietal properties that could be used to identify a variety. Kernel type and dimensions are important to producers, millers, processors and breeders (Slaton *et al*., 2005; Gayin *et al*., 2009). Though the length and width of the seeds are varietal properties, environmental conditions during their growth could affect these qualities (Irshad, 2001). The length and width also influences the overall size and shape of the rice which is a factor that is highly considered by rice farmers, buyers, millers as well as consumers. Since the length and width of the seed rice is of importance to those involved in the rice industry, these characteristics are seriously considered in the breeding of new varieties (Slaton *et al*., 2005). Depending on the need of the farmers, buyers, millers and consumers, any of the varieties could be useful, though varieties grouped as very long and long are likely to produce long grains upon milling which are liked by the Ghanaian consumers.

Grain length and Grain length to width ratio

Since rice is produced marketed according to grain size and shape, determining the physical dimensions of the varieties are very important. The varieties were categorized into three groups as extra long, long and medium based on the length of their milled grain using a scale set by Belsnio (1980). Belsnio (1980) and Richman *el al*. (2006) used the length of the rice milled kernel to determine its size. Takoradi (2008) reported that long grain rice is highly demanded by the Ghanaian rice consuming populace. The length to width ratio was further use by Richman *et al* (2006) to classified milled grain. The varieties were categorized into two types, slender (27 varieties) and medium (19 varieties) based on their length to width ratio. A positive relationship was observed between the hulled grain length and the milled grain length (r=0.96).

Germination and Vigor

Seventy six percent of the varieties (35 varieties) had germination percentage of over 80%. This is in accordance with the acceptable minimum standard of certified seeds in Ghana as reported by Ocran *et al*. (1998). A positive relation was observed between seedling vigor and germination among the varieties similar to the report by Maquire (1962). Those varieties with high germination percentage also had high vigor percentage and vice versa. According to IRRI (2009) seeds high in vigor provide for early and uniform stands which give the growing seedlings good resistance against various environmental stresses. Variation in the performance of the varieties during the vigor test implied that some of the varieties with low vigor will lose their viability quicker than those with high vigor when stored under the same conditions. Mahadevappa and Nandisha (1987), Richman *et al*. (2006), ISTA (2007) and Black and Halmer (2006) had earlier reported that seeds with low vigor lost their viability quickly than those with much higher vigor when stored under the same condition. IRRI (2009) reported that seeds low in vigor produce weak seedlings that are susceptible to environmental stresses while those with high vigor provide for early and uniform stands which give the growing seedlings good resistance against various environmental stresses. Lee *et al* (1986), Perry (1981) and Pollock and Roos (1972) reported that variations in seedling vigor and germination could be due to inherent characters or environmental factors acting on the plant during its growth and development.

Thousand Seed Weight

The thousand rice hulled weight varied from 27.2 g to 44.4 g. The varieties with long grain lengths also had the maximum thousand weight values (above 40g). These were CRI-74, CRI-45, CRI-62, CRI-38, CRI-19, CRI-16, CRI-9, CRI-1, CDU2 and N12. Mahadevappa and Nandisha (1987) indicated that heavier seeds produce vigorous seedlings responsible for high grain yields. A similar trend was observed during the germination and vigor tests in the current study with the exception of CRI-38. IRRI (2009) reported that longer grains are lighter in weight than medium or bold grains but the contrary was observed in this study, probably because most of the varieties used had long grains. These varieties were grouped based on their thousand seed weight as reported by Vanangamudi *et al*. (1987).

Milling Characteristics

Khush et al. (1979) describe milling yield of rough rice as an estimate of the quantity of head rice and total milled rice (milling recovery) that can be produced from a unit of rough rice. From the results obtained, the varieties were grouped into four categories based on the percentage values obtained from the percent milling recovery (whole plus broken). The four groups are premium (>70.0%) 1 variety, grade 1 (>65.1<70.0%) 7 varieties, grade 2 (>60.1<65.0%) 25 varieties and grade 3 (>55.1<60%) 9 varieties as reported by (RTWG, 1997). Four varieties did not fit in any of the categories set by RTWG, (1997). This shows that varieties resist breakage differently during milling. The higher the milling recovery percentage, the smaller the breakage and vice versa. Although it is reported that long grains break easily compared to shorter grains, observation in this research shows that variety ARCCU2Fa9-L3P3-B-B-4, premium milling quality variety with longer grains had higher milling recovery and lower breakage contrary to earlier report by IRRI (2009). From the results obtained from the study, the varieties were categorized on the basis of their percent head rice into four groups; premium (5 varieties), grade 1 (29 varieties), grade 2 (7 varieties) and grade 3 (1 variety) using RTWG (1997) criteria. According to Mutters (1985) broken grains are usually valued less (30-50%) than whole grains; therefore varieties with less broken grains will accrue more profit from sale than their counterparts with higher broken grains.

Pasting Characteristics

Significant differences were observed in the pasting characteristics of the starch of the varieties studied. The peak viscosity ranged from 46 BU to 201 BU (Appendix 1) which was far lower than the peak viscosity reported by Juliano (1985). The cool paste viscosity ranged from 136.5 BU to 380.5 BU was also lower than the cool paste viscosity reported by Juliano (1985). The set back viscosity ranged from 94.5 to 231BU (Appendix 1) which is lower than the reported values (200-700BU) by Juliano (1985). Only seven (ARCCU2Fa9-L3P3-B-B-4, ARCCU3Fa7-L3P3-B-B-1, ARCCUFa3L7P1-B-B-1, ARCCU3Fa12L8P1-B-B-1, N12, CRI-26 and CRI-75) of the varieties fell within this range. These varieties all had their breakdown viscosity values above 20BU except variety ARCCU2Fa9-L3P3-B-B-4 (19BU).

The values obtained from peak, hot paste, cool paste, breakdown, setback, and setback viscosities were in conformity with Gayin *et al*. (2009).

The hot paste viscosity of the varieties did not change very much from the peak viscosity in most of the samples measured.

From the breakdown viscosity values, the least values (0.0–10.9 BU) were recorded in 29 varieties, intermediate values (10.1-19.9BU) were recorded in 5 varieties and high values (above 20BU) in 12 varieties. Gayin *et al*. (2009) reported that grains of the varieties with least values tend not to stick together when cooked (cooked dry) while those with high values stick together upon cooking. Those varieties that cooked dry are ideal for preparing fried or jollof rice in Ghana while the rest could be used for other purposes including preparing 'umo tuo' or porridge as suggested by Takoradi (2008) and Anon (1994).

At the end of the cooling period, the cool paste viscosities of all the varieties showed doubling effect or more from their hot paste viscosity. These findings are in conformity with those of Gayin *et al*. (2009).

Gelatinization temperatures ranged from 75.9°C to 91.9°C which agree with the findings of Gayin *et al*. (2009) in Ghana. A positive relationship was observed between the gelatinization temperature and pasting time (y= 0.545x – 22.98; R^2=0.636). This implies that 64% of the variation in pasting time of the varieties is due to differences in their gelatinization time.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1: CONCLUSIONS

The rice varieties studied showed great diversity in their seed, grain and starch qualities. From the results of the study, the following conclusions can be made:

1. Seed length, width and thickness varied among the varieties studied.
2. The sizes of the rice varieties in this study were of three categories; extra long (>7.5mm), long (>6mm<7.5mm) and medium (>5mm<6mm).
3. Long grains with good milling recovery quality could be useful traits to be considered in the development of new rice varieties.
4. The rice varieties showed high vigor and germination percentage after 45 days of storage indicating the absence of marked dormancy among the varieties.
5. The germination percentage was high with 76 percent of the varieties above 80% after 45 days of storage.
6. The head rice recovery of the varieties ranged from 38.8% to 60.1%, with 29 varieties categorized as Grade 1.
7. Forty-two varieties fitted in one of the four milling (premium, grade 1, grade 2, and grade 3) categories excluding CRI-54, CRI-9, CRI-34 and CRI-7.
8. Differences were observed in the breakdown viscosity of the varieties studied which affect their cooking quality.

9. Twenty-nine varieties cooked dry, 12 varieties stick together upon cooking and 5 varieties neither stick together nor cook dry.

10. Based on all of the parameters studied, 29 varieties (CRI-35, CRI-50, CDU2, CRI-33, CRI-45, CRI-19, CRI-46, CRI-62, CRI-58, 1DSA85, CRI-42, CRI-37, CRI-51, CRI-41, CRI-1, CRI-71, CRI-44, CRI-16, ARCCU2Fa9-L3P3-B-B-4, CRI-74, CRI-40, N12, N15, ARCCU3Fa12L8P1-B-B-1, ARCCU3Fa7-L3P3-B-B-1, CRI-26, CRI-11 and ARCCFa3L7P1-B-B-1) are recommended for multiplication and onward distribution to farmers to increase the number of varieties that farmers and consumers can choose from.

6.2: RECOMMENDATIONS

1. Future work be carried out on the cooking and eating properties to see the relationship between the starch properties of the grain and cooking quality.
2. Data on physical characteristics and starch qualities could be used to select promising and adaptable varieties that are preferred by consumers in Ghana.
3. Germination and vigor test be conducted on the varieties at different storage period to determine their storage potential.

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APPENDICES

Appendix 1: Data on the varieties Pasting Characteristics.

Varieties	Peak Viscosity	Hot paste Viscosity	Cool Paste Viscosity	Breakdown Viscosity	Setback Viscosity	Gelatinization Temperature	Pasting Time
ARCCU3Fa7-L14P8-B-B-1	115	122	266	20	170.5	83.75	23
ARCCU3Fa9-L6P5-B-B-2	109	106	256	14	161	81.3	21.25
ARCCU2Fa9-L3P3-B-B-4	123	122	318	19	213	86	29.18
ARCCU3Fa7-L3P3-B-B-1	178.5	174	380.5	29.5	231	85.75	24.28
ARCCU3Fa3L7P1-B-B-1	171.5	155.5	323	50.5	202	83.3	22.43
ARCCU12Fa1L6P7-24-1-1-2	70	67.5	199	0.5	128.5	84	23.05
ARCCU3Fa12L8P1-B-B-1	194.5	174.5	335	62.5	203.5	81.85	21.43
ARCCU3Fa9L6P1-B-B-1	127.5	119.5	289.5	30	192	79.9	20.3
N12	175	163.5	349	50	223	83.4	22.48
N15	184.5	181.5	341	36.5	192.5	85.75	24.35
CDU2	89	81.5	245	0	156.5	80.3	20.43
CRI-1	95.5	83	265	0.5	169.5	86.7	25.03
CRI-4	59	45.5	192.5	0.5	134.5	83.7	23
CRI-5	46	36.5	136.5	0	90.5	88.65	26.18
CRI-7	97.5	222.5	91.5	10	135	77.55	18.5
CRI-8	100.5	94	283	1	184	83.85	23.1
CRI-9	83.5	65.5	214.5	0.5	131.5	86	24.38
CRI-11	164	159	324	33.5	193.5	85.3	24.08
CRI-16	110	107.5	97.5	12.5	174	79.4	20.03
CRI-19	105	78	285.5	0	180	87.5	25.4
CRI-20	60	57	161.5	0.5	102	8.85	22.3

Appendix 1 continues

Varieties	Peak Viscosity	Hot paste Viscosity	Cool Paste Viscosity	Breakdown Viscosity	Setback Viscosity	Gelatinization Temperature	Pasting Time
CRI-22	75.5	74.5	189	1	122	81.45	21.38
CRI-26	161.5	147	130.5	30.5	213.5	77.85	19.05
CRI-33	53	43	152.5	0	99.5	87	25.18
CRI-34	90	86.5	242	0	151.5	85.1	24
CRI-35	88	82	263	0.5	175.5	86.5	24.53
CRI-37	51	41	161	0	110.5	87.8	25.43
CRI-38	99.5	79	249.5	0	149.5	85.85	24.25
CR1-40	164	151	315	41.5	191	80.45	20.48
CRI-41	61	52	163.5	0	102	85.5	24.1
CRI-42	101.5	84	232.5	0	130.5	85.05	23.53
CRI-43	86.5	78	182	13.5	109	75.9	17.53
CRI-44	126	122	296	11.5	181.5	80.7	20.58
CRI-45	79.5	68.5	237.5	0	158	77.65	18.53
CRI-46	83	75.5	223.5	0	150	84.95	23.7
CRI-48	68	59.5	204.5	0	135.5	86.7	24.58
CRI-50	88.5	87	277.5	1	190	83.75	23.03
CRI-51	83.5	78.5	219.5	0.5	137	84.3	23.28
CRI-54	55.5	41.5	150	0	94.5	86.3	24.48
CRI-58	63.5	52.5	169	0	105.5	83.5	22.33
CRI-62	94	70	239	0.5	145.5	86.3	24.48
CRI-71	81	65	241.5	0	161	86.55	24.58
CRI-74	201.5	176.5	318.5	71	187.5	91.9	21
CRI-75	170.5	168.5	364.5	36	229.5	86.3	24.45
ISDA85	97.5	95.5	268.5	0.5	171.5	85.1	23.55