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GRAIN QUALITY CHARACTERISATION OF 87 RICE (*Oryza sativa*) ACCESSIONS IN GHANA

BY

ALEX TAMU

B.Sc. (Hons) Crop Science (Njala University, Sierra Leone)

JUNE, 2015

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A thesis submitted to the Department of Crop and Soil Sciences, Faculty of Agriculture, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana in partial fulfillment of the requirement for the award of Master of Philosophy Degree in Agronomy

(Plant Breeding)

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DECLARATION

I hereby declare that except for references to works of other researchers, which have been duly cited, this work is my original research and that neither part nor whole has been presented elsewhere for the award of a degree.

Alex Tamu	………………………..…	………………..
(Candidate)	Signature	Date

CERTIFIED BY:

Prof. Richard Akromah	………………………..…	………………..
(Supervisor)	Signature	Date

Dr. Enoch. A. Osekre	………………………..…	………………..
(Head of Department)	Signature	Date

ABSTRACT

A study was conducted to evaluate grain appearance, cooking and eating quality of 87 rice accessions. The experiment was laid out in randomized complete block design with three replications. The highest grain weight value of 4.05g was obtained for variety CRI-2 and the lowest was recorded for variety N22 with mean value of 1.81g. Based on grain length classification, the 87 accessions were grouped into three of which 32 of the accessions exhibited long grain length, 49 were medium grain length while 6 accessions recorded short grain length. For gel consistency measured, 22% of accessions recorded medium gel 71% obtained hard gel and 7% were soft. From accessions studied 66% recorded non aroma and 34% were highly aromatic. Variety IR 81412-B-B-82-1 recorded the highest L/B ratio and the least was found in variety GR 21.The minimum elongation ratio was recorded in variety WAB2125-WAC BTGR3-WAT B1, while maximum exhibited in variety IR 74371-54-1-1. The longest length after cooked was recorded for variety SIK-353-A 10 and the least for GR-21.The largest width increase during cooking was recorded in WAB-2081-WAC BTGR4- B (3.47 mm) and the lowest for TXD 88 (2.53mm). Variety DKA recorded minimum volume expansion ratio, while the maximum was exhibited for variety FAROX 15. The maximum water uptake was recorded in variety PHKA RUMDOM, while variety DKA had the lowest. In this study, alkaline spread value had significant positive and strong correlations with gelatinization temperature (r =1.00***). Gel consistency and gelatinization temperature exhibited non- significant correlation among themselves. Gelatinization temperature highly positive weak correlations with volume expansion ratio (r =0.33***).and water uptake (r= 0.27***). The characteristics of the various grains make them suitable for different food preparations and meet the preferences of wide categories of consumers.

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DEDICATION

I dedicate this work to my parents Mr. Sheku Tamu and Mrs. Mariama Tamu for their inspiration and guidance during the course of this work.

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ABBREVIATIONS AND ACRONYMS

ASV;	Alkaline spreading Value
AC;	Amylose Content
ANOVA;	Analysis of Variance
CPV;	Cool Paste Viscosity
CSIR;	Council of Scientific and Industrial Research
ER;	Elongation Ratio
FAO;	Food and Agricultural Organization
FAOSTAT;	Food and Agricultural Organization Statistics
GC;	Gel Consistency
GT;	Gelatinization Temperature
GBSS;	Granule Bound Starch Syntheses
GLAC;	Grain Length after Cooked
GWAC;	Grain Width after Cooked
HPV;	Hot Paste Viscosity
IRRI;	International Rice Research Institute
KOH;	Potassium Hydroxide
LBV;	Low Breakdown Viscosity
L.W;	Length Width Ratio
LSD;	Least Significant Difference
LAT;	Leaf Aromatic Test
LSDM;	Least Significance Differences of Means
MoFA;	Ministry of Food and Agriculture
NPK;	Nitrogen Phosphorus and Potassium
PV;	Peak Viscosity
QTL;	Quantitative Traits Loci.
SRID;	Statistics Research and Information Direction.

SED;	Standard Errors of Means
SEDM;	Standard Errors of Differences of Means
SSECV;	Stratum Standard Errors and Co-efficient of Variation
SSA;	Sub- Sahara Africa
VER;	Volume Expansion Ratio
WARDA;	West Africa Rice Development Association
WUV;	Water Uptake Value

CHAPTER ONE

1.0 INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops produce worldwide and covered one fifth of cereal population (Zhout *et al*., 2002). Rice is normally grown as annual plant, although in tropical areas it can survive as a perennial and can produce a ratoon crop for up to 30 years (IRRI, 2009**).** About two third of the world population depend wholly on rice for their basic food consumption (Patil *et al*., 2014). Rice is the primary source of income and employment for more than 100 million households in Asia and Africa (FAO, 2004). Generally, it is extensively consumed in the producing countries and constitutes about 20% to 50% of total caloric consumption of many countries in the world (Nutsugha *et al.,* 2004). It is a primary source of energy for 17 countries in Asia, 9 countries in North and South America and 8 countries in Africa. FAO (2004) stated that rice provides major dietary energy supply (20%), followed by wheat (19%) and maize (5%).

The paddy rice production in the world amounted to 722,760,295 tons in 2011 on a cultivated areas of 106,412,497 hectares while the cultivated area in African was 9,383,330 hectares with an average production 24,511,877 tons (FAOSTAT, 2013). According to WARDA (1996), revealed that West Africa includes Senegal; Mali, Cote D"Ivore etc are the leading producers and consumption of rice in the Sub-Sahara Africa. The production and distribution of rice in Sub-Sahara Africa reported by (WARDA, 2000) was about 42%, 32%, 24%, 1% and 1% were produced in West, North, East, Centre and South Africa respectively.

In Ghana rice is an essential staple cereal food crop due to rapid urbanization and it is consumed by almost every family, per capita consumption of rice increased from 17.5kg to 38kg between the year 1999 -2008 and expected to get to 63kg by the year 2018 (MoFA, 2009). Since 1980, the importation of rice has drastically increase in Ghana were the consumption of rice outweigh domestic production. About 70% of rice consumed in Ghana is imported (Bam *et al.*, 1998). According to the 2010 budget statement, about USD 600 million is spent on importation of rice forever year (Duffuor, 2009).

Nanda (2000) stated that grain quality is one of the major issues in rice production. It is one of the selection principles prioritized by farmers and consumers of rice and consequently farmer choose rice with traits that are needed for consumption as well as for production and sale (Horna *et al*. (2005). Cooking and eating qualities are the major constituents that contribute to grain quality. Bergman *et al.* (2004) reported that biochemical components such as aroma, amylose content, gel consistency, alkaline spreading value and gelatinization temperature control cooking and eating qualities. According to Singh. (2000) quality is best defined based intended end use of the grain by the consumers. Quality in West Africa is centered on the type of food been prepared by people for eating. Efferson. (1985) stated that long and aromatic grain is mostly liked in Middle East while non-aromatic grain type is liked by consumers in European community were the presence of aroma show indications of contagion and spoilage. Long grain, slender shape and aromatic rice have the greatest demand and are used with sauces or to prepare jollof or fried rice (Takoradi, 2008). Short and medium rice grain are used in making porridge, while broken grain is used for fried rice in West Africa includes Senegal, Mali, and Gambia (Anon, 1994).

Large importation of rice in Ghana to supplement shortfalls, are becoming a disincentive to local production. Despite an increase in domestic rice production in the economy of Ghana, but most Ghanaians prefer imported rice due to poor grain quality of the former (Diako *et al*., 2010). Although breeding for improved grain quality has recently become a major focus in Africa, genetic studies on grain quality traits is inadequate. Therefore there is an urgent need to characterize the rice germplasm available to breeders in Africa to improve grain quality traits thus, this will aid the selection of the appropriate genotypes for breeding high quality of African rice that meet the market standards, hence reducing the importation of rice.

The main objective was to characterize rice accessions for their grain quality and facilitate the selection of the appropriate genotypes for breeding.

The specific objectives use to:

I. Characterize a set of rice germplasm for their appearance quality (Grain length, width, chalkiness and translucence).

II. Characterize a set of rice germplasm for their cooking and eating quality.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Rice Taxonomy and Botany

Rice is cereal crop and primary food source for more than one third of the word population; it is a widely consumed cereal food in the world (Singh and Singh, 2008). According to FAOSTAT (2012), rice is classed third in term world production after sugarcane and maize. Poaceae is the family to which rice belongs and subfamily Bamboosoideae. This tribe oryzeae consist of 11 genera with the genus Oryza being the only cultivated species with 24 extral species, two of which are cultivated. Oryza sativa (Asian rice) is cultivated throughout the world while Africa glaberrima is cultivated on a small scale in West Africa. The two cultivated rice species originated from a common ancestor with AA genome and are thought to be an example of parallel evolution (Khush and Virk, 2000). O. sativa is diploid, with 12 chromosomes (2n=24). O. sativa is broadly divided based on morphological and physiological characteristics into japonica, indica, and javanica subspecies. The genus Oryza consist of twenty two wild species of rice, nine of the wild species are tetraploid and the remaining wild species and the two cultivated species are diploid (Dogara and Jumare, 2014). Both O. sativa and Oryza. glaberrima are normally grown as annuals although

O. sativa may be maintained as a perennial if protected from frost and drought (Sohl, 2005). Rice can grow to 1–1.8 m (3.3–5.9 ft) tall, occasionally more depending on the variety and soil fertility. It has long, slender leaves 50–100 cm (20–39 in) long and 2–2.5 cm (0.79–0.98 in) broad. The small wind-pollinated flowers are produced in a branched arching to pendulous inflorescence 30–50 cm (12–20 in) 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).

2.2 Origin and Distribution of Rice

Rice is grown under diverse cultural conditions and wide geographical range. Rice belongs to the genus group called Oryza and it was name since130 million years ago (Dogara and Jumare, 2014). Rice as a wild grass originated from Gondwanaland (Asia, Africa, Australia, and Antarctica) and is wildly dispersed in the world (Dogara and Jumare, 2014). Rice is native to Southeast Asia, but has extented throughout tropical and sub-tropical environments (Vaughan *et al.*, 2003). Most of the world"s rice is cultivated and consumed in Asia, which constitutes more than half of the global population. About 11% of the world"s arable land is annually cultivated with rice and ranked as first followed by wheat (Patil *et al*., 2014). Boumas. (1985) stated that Asia, Latin America, and Africa are the main rice growing areas and Asia is the main exporting continent. About 90% of rice cultivation area is found in Asia whereas the remaining 10% is cultivated in United States of America, Latin America and Africa (Courtois *et al*., 2007). According to FAOSTAT (2013), the world production of paddy rice in 2011 was 722,760,295 tons from a cultivated area of 106,412,497 hectares while the African production was 24,511,877 tons from a cultivated area of 9,383,330 hectares.

2.3 Rice Ecosystems in Africa

Rice is grown under various growing environmental conditions with varying temperature and water supply. Rice ecosystems includes Irrigated, Rainfed lowland, Rainfed upland and mangrove. Since 1971 the West Africa Agricultural Development Association (WARDA) did tremendous work in the development of rice varieties and technology for different synthesis system (WARDA, 1993).

2.3.1 Irrigated Ecosystem

The performance of rice in irrigated areas has shown a better output. According to (WARDA, 1993) output of rice in irrigated areas doubled more than five tons per ha in the past 30 years and there is possibility for further improvement of yield. In Africa, (Egypt, Niger, Mauritania) practice 100% irrigation rice farming whereas Madagascar used 31% of its area irrigated land for rice production (WARDA, 1993). With good agronomic practices and the used of improved technology in irrigated ecosystem yield will increase from 5 to 7 tons/ha (WARDA, 1993). Dobermann and Fairhurst (2000) reported that irrigated area accounted for about 55% of the global harvested areas and contributes 410 million metric tons (75%) of global rice production, per year. The major bottleneck associated with irrigated systems includes: huge sum of capital, nutrient deficiencies, acidity, weeds, diseases (Rice yellow Mottle Virus), blast, sheath rot, and bacterial leaf blight) and insects such as gall midge, and stem borers (Traore, 2005).

2.3.2 Rainfed Upland Ecosystem

Upland ecosystem is ecology where rice is cultivated under natural rainfall with the absence of manmade irrigation system. Rice is also produced in dryland, deforested and rainfed areas (Poehlman and Sleper, 1995). Also this ecology is characterized by poor soil fertility and capable of holding water for longer period. The major problem associated with this ecology is the destruction of watershed during sifting cultivation. This practice is common in West Africa and covers up to 57% of the production areas and accounted for 44% of the total output produced (WARDA, 1993). Countries in West Africa that commonly practice upland cultivation include Sierra Leone, Liberia,

Cote d‟ivoire, Nigeria and Guinea Bissau (WARDA, 1993). About 1ton/ha of rice is produced in this system and the low yield is associated with low weed control, soil acidity, pests, insects and others (Johnson *et al*., 1998).

2.3.3 Rainfed Lowland Ecosystem

Rainfed lowland ecosystem is an ecology where rice is grown in wetlands and the field is surrounded by bunds and characterized by flooding and drying due to erratic patterns of rainfall. IRRI (1986) lowland rice production accounted about 38.3% of rice production in the world. It is seen in the same report that Africa and Latin America have vast rainfed lowland but with little production while Asia with little lowland accented 36.7% of the low land production. In South and Southeast Asia the expansion of low lowland cultivation is declining due to the high irrigation, whereas Africa and Latin America have potential to expand in production. It is estimated that a total of 130 million ha of inland valleys are available for cultivation in Africa, 19 million ha of which (14.6 percent) occur in West Africa (WARDA, 1993). This ecology is characterized by unstable water table and declining water during the dries. The quantum of yield harvested in rainfed lowland ranges from 1.4 to 5 ton/ha compared to rainfed upland 1ton/her (WARDA, 1993).

2.3.4 Mangrove Swamp Ecosystem

Mangroves have high levels of salinity brought by salt water intrusion caused by tidal waves of the sea, although almost all the mangroves enjoy a free period of salt during the rainy season as freshwater floods wash the earth. This period shortens, from over six months to less than four years, with increasing proximity to the sea, which allow rice crop to grow. In this ecology, the average yield is 1 to 2.2 tons / h compared to rainfed upland. Mangroves cover an area of 1.2 million / ha and only 193,000 ha have been developed (WARDA, 1993).

2.4 Rice Production in Africa

In Africa, rice has increasingly become popular and about 100 million people depend on it for their livelihoods (Nwanze *et al*., 2006). According to FAO. (1996). Africa holds an average paddy rice of 14.6 million tons per annum from 1989 to 1996 on a cultivated land area of 7.3 million ha, comparable to 2.6 and 4.6 % of the total rice production areas in the world. Rice production in Africa is mainly concentrated in North and West Africa. These regions constituted about 73% of the total rice production in 2013. West Africa is about 6 million km2 in area, and rice occupies about 8% of the total cropping area, ranking fifth in area, after millets 21%, sorghum 19%, maize 12% and cassava 9%; and rice is then followed by yams (5%) (FAOSTAT, 2009). West Africa covered of about 4.1 million hectares of the vast available areas for rice production. However, Africa had a total rice harvested area of 10,931,051 hectares and a total production of 29,318,488 tons in 2013.

West Africa recorded a total harvested area of 6,412,136 hectares and total production of 14,500,784 tons, While North Africa also reported a total harvested area of 712,742 hectares and a production total of 6,813,036 tons in 2013 (FAOSTAT, 2015). Therefore, West Africa accounted about 58.7% of harvested area and 49.5% of total rice production in Africa in 2013.

2.5 Rice Production in Ghana

Although, maize is the major cereal crops produce in Ghana it has been observed that the production and consumption of rice has steadily increase in all region and all the major ecological-climatic zones of Ghana due to the contribution to the Gross Domestic product (GDP). It serves has source of income and provide jobs for the rural household (MiDA, 2010; Osei-Asare, 2010). The distribution of rice in the follow ecological zone is as followed: Rainfed accounted about 78%, irrigated 16% and inland valley accounted for 6% (Oteng, 1994). Oteng. (1994) reported that about 80 % of production of rice is done in the interior savanna while 60% is cultivated in the hydromorphic ecology. About 73 of the total land area of rice are fund in three major region Northern, Upper east and Volta regions while 27% land cultivated are found the remaining regions (SRID, 2006). The three regions also accounted for 80% of the national output production in Ghana. In these three regions, an average yield of 2.96 MT/ha surpasses the national average of 2.71 MT/ha but is considerably lower than the average yield of 5.48 MT/ha in the Greater Accra region (SRID, 2006). The land area harvested for 2013 was 215,905 hectares and total production of 569, 524 tones. Recurrently, Ghana experience (3%) and (9%) increase in harvested area and total production between 2012 and 2013 respectively (FAOSTAT, 2015).

According to Ghana Government (1996) an average yield of 173.2 tons of paddy rice was achieved per annum between 1981 and 1996 (ranging from 131.5 to 215.7tons), with in the same era there was an increase of 1.5 tons/ha in 1990 to 1.9 tons/ha 1996, equivalent to an increase 26.7% .

2.6 Economic Importance of Rice

The high consumption and production of rice has made it the most important cereal crops in the world. About 50% of the global population consumed rice for their basic dietary energy (Basorun, 2003). Rice has been an important food commodity for most people in sub-Saharan Africa, particularly, West Africa. In Ghana majority of the household consumed rice in different forms such as plane rice boiled or fried with stew, curry, paella, risotto, pancit, and beans with rice. FAO (2004) reported that 114 developing countries in the world cultivate rice for their daily meal and also serve as source of income, and major employment for rural household. Erhabor and Ojogho (2011) indicated that consumption of millet and sorghum has decreased from 61% to 49% between 1970 and 1990 whereas rice consumption increased from 15% to 26% within the same period.

An increased in consumption of rice over the other cereal crops can be explained by these factors easy to prepare thereby reducing the choice of other cereals food preparation and fitting more simply in the urban lifestyles of reach and poor alike (Kadiri, 2014). Also rice supplies about 20% of the world‟s dietary energy whereas wheat supplies 19% and maize 5% (FAO (2004). FAO (2008) mentioned that rice represents 27% of energy and 20% of alimentary protein. The germ and the husk which are eliminated during threshing are rich in vitamins – especially vitamin B1 – minerals, fibre and enzymes. The byproducts of rice have numerous uses; „tatamin‟ mat made from rice straw, beer or sake brewed from rice, rice vinegar for seasoning rice, rice bran for animal feed and rice hull for generating energy; creating synthetic fiber as well as fertilizer (FAO, 1996). The complex carbohydrate in rice digests slowly allowing the body to use the energy released over a long period which is nutritionally efficient (Ebuehi and Oyewole, 2007).

2.7 Constraints to Rice Production

FAO (1996) reported that Africa countries consumed of about 11.6 million tons of rice and about 3.3 million tones are imported every year. Africa's incapacity to meet demand in rice output is as the result of numerous constraints attributed to both production and processing mechanism. There is a need of an urgent ways of reducing over-reliance on importation and to mollify the increasing demand for rice in areas where the potential of local production resources is exploited at low level due to the following factors: weed competition, drought, soil acidity, soil infertility, the use traditional tools and among others factors that courses the low production of rice in Africa (Johnson *et al.,* 1997).

2.7.1 Drought

Drought is one of the most major restricting factors that influence the production and cultivation of rice in many part of the world (Passioura, 2007). Scarcity of water during drought or low rainfall period is serious problem affecting the vegetative growth rate and grain yield of rice (Tao *et al.,* 2006). Bouman *et al*. (2005) revealed that drought accounted for 50% of low cultivation of rice and 40% yield losses in most of the world including India. Its represents a substantial environmental pressure for rice production, with 19 to 23 million hectares of rain fed rice cultivation in South and South East Asia is at risk in production (IRRI, 2013). Secondly, during the vegetative growth, flowering, and fatal stages water is needed most to carry out this aforementioned (Kamoshita *et al.,* 2004). Drought also has the various effects on rice by coursing early senescence and shortens the grain-filling, spikelet sterility and unfilled grains (Plaut *et al.,* 2004). The impact of drought driven by erratic rainfall and poor water control in rainfed lowland ecosystems affects output of rice growing areas by 80%, 67% and 48% in Mali, Burkina Faso and Nigeria respectively http;// www. generationcp.og/ research/research-initiatives/rice.

2.7.2 Insects Pest

Pests are microorganisms that reduce output or value of the rice product in both field and storage areas (Jahn *et al.,* 2007). The various parts such as root, stem, leaves and also the vegetative parts are distort by various species of rice pests. There are about 800 difference insect species that damage rice in both production and storage areas world wild (Cohen *et al.,* 1994). Cohen *et al.* (1994) also reported that about ten (10) major species of insect pests course serious problems in West Africa rice production. The damage caused by these species varies from country to country, from verities to verities and so on. Leafhoppers and plant hoppers are the major insect pests among other species that solemnly cause significant yield losses in rice production. The also transmit other viruses, stem borers; and a group of defoliator species (Jahn *et al.,* 2007). Cramer, (1967) indicated that about 31.5%, of yield in Asia and 21% in North and central America is as a result insects pest damage.

2.7.3 Diseases

Rice blast (magnaporth grisea) is a fungus disease that cause seriously treats in rice production areas in Africa (Dean *et al.,* 2005). Blast can affect all stages of crop growth and any organ of the plant such as leaf, sheath, neck, panicle, rachis, stem node and grains. Ou, (1985) reported that rice blast can consequence lead to about 70% to 80% of yield loss. According to Candole *et al.* (2000) rice blast can cause substantial decrease in grain bulk density and yield of rice. Sheath blight, rice ragged stunt (vector: BPH), and tungro (vector: *Nephotettix* spp) are other major diseases that causes drastic yield reduction in rice (IRRI, 2012). Brown spot of rice has been overlooked as one of the most detrimental rice diseases. It is mostly common in rainfed and upland areas. This disease attacks the crop from the seedling stage in the nursery to the milk stage in the field. Spots vary in shape and size and appear on the coleoptiles of the leaves, leaf sheath, and glumes (http://www.apsnet.org/ publications /

imageresources/Pages/fi00175.aspx). Brown spot is another yield reducing factors that has also been reported in rice growing areas in the world. *Savary et al.* (2000) also reported that about 5% of yield loss in lowland production areas in South and Southeast Asia is as a result of brown spot damage.

2.7.4 Weeds

Weeds are the major biotic constraint to increased rice production worldwide. The importance of their control has been emphasized in the past by various authors (De Datta and Baltazar, 1996; Labrada, 1996; Ze-Pu Zhang, 1996). The prime restrictions to rice cultivation in direct-seeded areas are the occurrence of red rice, which is widespread all over the world. West Africa Rice development Association stated that about 27% to 37% of the entire labor for rice cultivation is due to weed control. As compared to cereals like sorghum and maize, rice is very slow in establishing its canopy thereby causing weed competition for soil nutrients, light and moisture (DeVries and Toenniessen 2001). In West Africa *Oryza barthi* and *O. longistaminata*, are among different weed type that cause yield reduction in rice According to West Africa Rice Development Association (WARDA, 1999) reported weeds can reduce about 25% to 40% yield loss in rice and may also lead to total crop failure if they are left uncontrolled.

2.8 Rice Grain Quality and it`s Components

Nanda (2000) stated that grain quality is one of the major concerns in rice production. The grain quality of rice has recently attracted a lot of attention around the world, including Africa. Grain quality features are among important factors prior to variety adoption. These characters include physical (milling quality, grain length and shape) and biochemical (amylose content, gelatinization temperature gel consistence, and aroma).

Rice quality differs according to the variety and processing method used (Pomeranz, 1992). The differences in quality which are mainly attributed to differences in colloidal structure and the extent of swelling of any variety of rice on cooking have always been used as index of its quality (Oko *et al.*, 2012). Martinez *et al.* (2005) reported consumer"s ultimatum for better grain quality can also influence its production. Consumers" choice of rice varieties are largely based on grain and cooking qualities. In Africa rice production is market oriented where quality becomes a primary concern. Normally rice is consumed as a whole grain where physical properties (grain length, grain width), cooking quality (elongation ratio, water uptake), and aromatic traits are essential. Grain quality is a very wide area encompassing diverse characters that are directly or indirectly related to exhibit one quality type (Siddiqu*i et al.*, 2007**)**. The gelatinization temperature (GT), gel consistency (GC) and amylose content (AC) are major rice traits, which are directly related to cooking and eating quality (Shilpa *et al.*, 2010). Different cultivars showed significant variations in morphological, physicochemical and cooking properties (Yadav *et al.*, 2007). As countries become self-reliant in rice production and living conditions are improved, human demand for high quality rice continually increases (Jena and Mackill, 2008). Consequently, the current trend is to breed for preferred quality characteristics that meet consumers „increasing demand for better quality rice (Tian *et al.*, 2009; Mohapatra, 2011).

2.8.1 Appearance Quality

Appearance quality of the grain rice represents a prime problem of rice production in many rice producing areas of the world (Tan *et al.*, 2000). It is another critical quality attribute for rice. Reports by Armstrong *et al. (*2005) stated that Consumers judge the quality of the rice base on the homogeneity of its size and shape as well as the appearance of its general size-shape relationship. According to Amarawathi *et al.* (2008) grain quality appearance is mostly determined by grain shape as specified by grain length, grain width, length-width ratio, chalkiness and translucency of the endosperm. Webb 1991 described Chalkiness in rice as" white belly", "white core", "white back", "germ tip", or "immature". Kushibuchi and Fujimaki (1975), revealed that components which contribute to grain chalkiness includes grain Moisture content, unripe kernels, climatic situations, and varietal features as well as cultural practices.

2.8.2 Grain size, shape and weight

Rice grain size and shape is critical in breeding new varieties as each variety must fit an existing Market class. Grain weight provides information about the size (length and width) and grain density. Classified pulverized grain rice into long grain with (6.617.5 mm) length and 3.1 and more as length-width ratio (Adair *et al.*, 1973). The medium grains have a length of 5.51 to 6.6 mm and a length-width ratio of 2.1 to 3, the short grains have up to 5.5 mm length and a length to width ratio of 2.0 and less. According to Rickman *et al.* (2006), milled rice grain categorized based on the length- width ratio as bold (> 1.1 <2.0), slender (> 3.0), medium (> 2.1 < 3.0), and round (< 1.1). Long slender grains normally have greater breakage than short, bold grains and consequently have a lower milled rice recovery. Preferences for grain size and shape vary across different countries and cultures. Even though the preferences of rice grain characteristics vary with different consumer groups, long and slender in rice is mostly favored by many consumers in china, USA and other Asia countries (Unnevehr *et al.*, 1992). Long grain quality varieties tend to produce dry fluffy and separated cooked grains, whereas medium and short grain varieties tend to produce clumped, moist and chewy grains after cooking (Webb, 1980).

2.8.3 Rice Cooking and eating quality

Many components contribute to rice quality; the most important are cooking and eating qualities. Rice cooking and eating characteristics are the bases of choice for the consumers cooking and eating quality of rice is determine by a combinative of objective and subjective criteria. The primary components of cooking and eating quality of rice are controlled by amylose content measured as apparent amylose content (AAC), gelatinization temperature (GT) measured as alkali spreading value (ASV), gel consistency (GC), grain appearance, cooked grain elongation, fragrance of cooked rice and paste viscosity profiles measured with rapid visco analyzer (RVA) (Bergman *et al.*, 2004). Even though, the environment and post-harvest handling can affect the quality of rice, quality is highly influenced by genotype (Amarawathi *et al.*, 2008). Cooked rice with low amylose content is sticky, moist, tender, and glossy while rice with high amylose content flaky, dry, hard, and separates (Juliano, 1979).

2.8.4 Amylose Content

Amylose content is an important constituent that influence that cooking, eating and the processing of characteristics of rice (Bao *et al.,* 2001). Rice consist of over eighty (80%) starch and at molecular level starch contains amylose (linear chains glucose of α (1-4) linkages) and amylopectin (branched chain glucose with α (1-6) linkage (Kettlewell *et al.,* 1996). Amylose content of rice is identified to play a critical role in determining its cooked texture. Amylose content (A.C) is directly related to water absorption, volume expansion, fluffiness, and reparability of cooked grains and inversely linked to cohesiveness, tenderness, and glossiness (Juliano, 1971). According to Suwannaporn *et al.* (2007), they group amylose content into three categories includes 0 to 5% as waxy, 5% to 12% as very low, 12% to 20% as low 20%

–25% intermediate and high ranging from 25% –33%, even considering that commercially rice is classified by amylose content as either low (less than 20% amylose), medium (21–25%) and high (26–33%). Rice with high amylose content hard once cooked. Non- waxy rice has intermediate amylose content and is often firm once cooked. Waxy rice often known as glutinous rice is sticky, soft and does not expand in length or width once cooked whereas rice with high amylose content becomes harder after cooked (Sood *et al*., 1983, Williams *et al.*, 1958; Rao *et al.*, 1952). Starch content (amylose) of rice is very important factors in grain yield, processing and palatability. It is well documented that environmental conditions, especially temperature during grain development, affect the cooking and eating quality of rice (Asaoka *et al.*, 1984; Shi *et al.*, 1997; Chen *et al.*, 2008). Amylose content was found not to be affected by timing of harvest or length of grain storage (Juliano,

1971), but high temperatures during grain filling are reported to cause a decrease in AAC (Lisle *et al.*, 2000). The *Waxy* gene encodes the enzyme granule bound starch synthase (GBSS). This enzyme Granule bound starch synthesis (GBSS) controls amylose synthesis in the grass family and classic grain cereals which comprises of approximately 20% to 30% amylose while amylopectin is 70% to 80% (Smith *et al.*, 1997; Preiss, 1990). Waxy gene consists of two wild classes of alleles which is in glutinous rice. There is no low amount of amylose in japonica rice with a wxb allele present, while as indica line contains high amount of amylose content with a wxa allele (Lanceras *et al.*, 2000).

2.8.5 Gelatinization temperature.

Gelatinization temperature is related to many factors such as cooking time, grain size, molecular size of starch fraction; it is also used as criteria classified rice in some countries. Like other factors it is also influenced by environment such as ripening temperature, genetic and rice varieties as well as cooking time (Kettlewell *et al.,* 1996). GT is responsible for cooking time, water absorption and the temperature at whichstarch irreversibly loses its crystalline order during cooking (Bhonsle and Sellappan**,** 2010). Gelatinization temperature is direct related to amylose contents; the higher the amylose the higher the gelatinization temperature, hence high waxy rice has higher gelatinization temperature than waxy or very low waxy rice (Zhong *et al.*, 2008). Rice with high GT tend to require more water and time to cook than those possessing either low or intermediate GT (Chatterjee and Maiti, 1985). GT is highly interrelated with alkali spreading value (ASV), which reflects the disintegration of milled rice in dilute KOH (Bergman *et al.*, 2004). Gelatinization temperature is influenced by many factors, such as the amylose and amylopectin content, granular morphology, degree of polymerization, and chain length distribution, as well as the presence of minor components such as lipids and phospholipids (Srichuwong and Jane, 2007).

According to Yamin *et al.* (1999), longer chains require a higher temperature, thus greater energy, to dissociate and disentangle the chain to initiate gelatinization than double helices with shorter chains. Wang *et al.* (2010), reported that a sets of waxy rice starches (low gelatinization temperature (GT) – 64-67°C, intermediate GT – 6871°C, and high GT – 48 75-79°C), found that the high-GT starches had longer amylopectin chains and higher crystallinity than the low-GT starches with more amorphous. Waxy starch from waxy hexaploid wheat and waxy maize starch swelled more rapidly and reached faster the peak viscosity compared to normal starches (Hayakawa *et al.,* 1997). The normal starches had higher set back than waxy starches. Juliano *et al*. (1985) reported that waxy and low amylose rice had low GT (GT<70) and they had higher glycemic index (GI) compared to intermediate and high amylose rice having intermediate GT. high amylose rice with different GT and cooked in optimum cooking water (68-69%), low GT rice had higher GI (91-94%) when it was compared to intermediate GT rice (62-71%).

2.8.6 Gel Consistency

Gel consistency is a measure of cold past viscosity of milled cooked rice flour, is a good index of cooked rice texture, especially among rice of high amylose content (Tang *et al.*,1991) eating quality is mostly determined by the gel consistency test. Cooked rice with hard gel consistency harden faster than those soft one while rice with soft gel consistency cook tender and remain soft even upon cooling (Juliano, 1979). Gel consistency known as GC is a measurement of the strength of the gel. The range of GC values to classify rice varieties according to this property is wide.

Samples are grouped into arbitrarily set classes based on the length of the gel: hard (length of gel < 40 mm), medium (length of gel 41-60 mm), and soft (length of gel > 61 mm) (Jennings *et al.*, 1979). Within the same amylose content, softer gel consistency rices are preferred by consumers (Khush *et al.*, 1979). It was found that among high AC varieties of rice, hard GC had longer amylopectin chain length (Takeda *et al.*, 1987) weak and rigid gels depend on the association of starch polymers in the aqueous phase (Dea, 1989). The GC is commonly measured by determining the length of a cooled gel made from flour previously cooked in 0.2 M KOH (Cagampang *et al.*, 1973). Most of these grain quality traits of rice are controlled by quantitative trait loci (QTLs) showing continuous variation in rice progeny (Yano and Sasaki, 1997; He *et al.*, 1999). However, GC is controlled either by the *wx* gene (Lanceras *et al.*, 2000) or by some QTL with minor effects (Bao *et al.*, 2000).

2.8.7 Aroma in Rice.

One of the most important grain quality traits in rice is aroma. Aroma is key criteria that determine market price of rice, and it‟s therefore related to both local and national identity (Fitzgerald *et al*., 2009, and Bhattacharjee *et al.*, 2002). There is an increasing demand for aromatic rice being driven by improving living standards of people around the world (Chen *et al.*, 2006). Different composites are also found in the headspace of perfumed rice varieties this may be due to secondary effect which is related to the genetic background of different rice varieties, also 2-acetyl-1-pyrroline is responsible for distinguishing jasmine and basmati fragrance (Widjaja *et al.*, 1996).Widjaja *et al.* (1996) also reported that 2- acetyl-1- pyroline is high in aromatic rice varieties but very small in non-aromatic rice varieties. Mixture of numerous volatiles controlled pleasant scent of non-fragrance or fragrance on raw or cooked rice varieties (Weber *et al.,* 2000). According to Bradbury *et al.* (2005) a recessive gene, on chromosome 8 of rice, largely controlling the level of 2-acetyl-1-pyroline, has been identified in genetic studies. The accessibility of a rice genome sequence provided an opportunity to discover the gene responsible by comparison of the sequences of aromatic and nonaromatic genotypes (Goff *et al.*, 2002).

2.8.8 Pasting Characteristics

Paste viscosity parameters play an important role in estimating the eating, cooking and processing quality of rice (Bao and Xia, 1999). According to Srzednicki *et al.* (2009) describes pasting as the phenomenon succeeding gelatinization when starch slurry containing surplus water is heated. Peak viscosity, hot past viscosity and cool paste viscosity are the three major amylographic viscosity characteristics, these amyl graphic characteristic are controlled by a single locus effect (Gravois and Webb, 1997, Mazurus *et al*, 1957). Limpisut and Jindal (2002) defines the peak viscosity as the highest viscosity value attained when the starch paste was heated while as hot paste viscosity was described as the lowest viscosity of the rice flour at 95C. Limpisut and Jindal (2002) also describe Low breakdown viscosity as the dissimilarity among peak and hot paste viscosity. Increase in paste viscosity is governed by the starch when it is cooled, this results in the absorbing of starch granules to be ruptured when held at high temperature and subjected to permanent shearing action which is measured by Breakdown viscosity, setback viscosity measured the degree of retrogradation.

2.8.9 100 Grain Weight

Abbasi *et al.* (1995) reported that hundred Grain weight is a yield-attributing trait which gives information about the density of the grain and its size. Uniform grain weight is very important for consistent grain quality. The weight of rice grains can vary considerably with moisture content, fertilizer treatment, weather conditions and the type of soil where the rice is grown. According to Rickman *et al*. (2006) that grain of diverse density mill differently, and are possible to cook and retain moisture differently.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The study was conducted at the Faculty of Agriculture Kwame Nkrumah University of Science and Technology (KNUST) (N 6.68º, W 1.57º) in the Ashanti Region Ghana from June to November 2014.

3.2 Source of Plant Materials

Eighty seven **(87)** rice accessions were obtained from different countries in the world for their gain quality characterization. (Table 3.1).

Table 3.1 Description of Rice Accessions

Entry No.	Accession Name	Source	Entry No.	Accession Name	Source
1	WAB2081-WAC B-TGR4-B	Africa Rice	44	SBT 70	Cameroon
2	WAB2125-WAC B-1TGR3-WAT B1	Africa Rice	45	BASMATI 113	Thailand
3	IR 841 (CHECK)	Africa Rice	46	L5O	CSIR-CRI
4	DKA-M2	Africa Rice	47	BASMATI 123	Thailand
5	JASMINE85	CSIR-SARI	48	CRI-30	CSIR-CRI
6	FAROX 508-3-10-F43-1-1	Africa Rice	49	CRI-2	CSIR-CRI
7	FAROX 508-3-10-F44-2-1-1	Africa Rice	50	CRI-45	CSIR-CRI
8	WAB 2098-WAC2-1TGR2-WAT B2	Africa Rice	51	CRI-73	CSIR-CRI
9	WAB 2056-2-FKR2-5TGR1-B	Africa Rice	52	CRI-48	CSIR-CRI
10	WAB 2060-3-FKR1WAC2-TGR4-B	Africa Rice	53	NERICA 1	Africa Rice
11	TXD 88	Africa Rice	54	AFRK-7	Africa Rice
12	WAB 2098-WAC3-1TGR1-4	Africa Rice	55	AFRK-8	Africa Rice
13	WAB 2076-WAC1TGR1-B	Africa Rice	56	AFRK-5	Africa Rice
14	WAB 2081-WAC2-2TGR2-WAT B3	Africa Rice	57	AFRK-13	Africa Rice
15	GBEWAA	CSIR-SARI	58	NERICA 4	Africa Rice
16	PERFUME IRRIGATED	Thailand	59	AFRK-6	Africa Rice
17	WAS-122-13-WAS-10-WAR	Africa Rice	60	AFRK-2	Africa Rice
18	LONG GRAIN ORDINARY 2	Thailand	61	AFRK-11	Africa Rice
19	EXBAIKA	CSIR-SARI	62	NERICA 14	Africa Rice
20	WAS-163-B-5-3	Africa Rice	63	AFRK-9	Africa Rice
21	FARO 15	CSIR-SARI	64	AFRK-3	Africa Rice
22	PERFUME SHORT	Thailand	65	AFRK-1	Africa Rice
23	KATANGA	CSIR-SARI	66	AFRK-10	Africa Rice
24	TOX 3107	CSIR-SARI	67	AFRK-12	Africa Rice
25	ANYOFULA	CSIR-SARI	68	AFRK- 4	Africa Rice
26	NABOGU	CSIR-SARI	69	IR 74963-2-62-5-1-3-3	IRRI

Con't: Table 3.1 Description of Rice Accessions

Entry No.	Accession Name	Source	Entry No.	Accession Name	Source
27	GR 21	CSIR-SARI	70	IR 81412-B-B82-1	IRRI
28	PHKA RUMDON	Cameroon	71	IR 55419-04	IRRI
29	MLI 20-4-1-1-1	Mali	72	IR 79913-B179-B-4	IRRI
30	DKA-M2	Mali	73	APO	IRRI
31	SIK 353-A10	Mali	74	N22	IRRI
32	DK 3	Mali	75	IR 77298-14-12-10	IRRI
33	MLI 6-1-2-3-2	Mali	76	KALIAUS	IRRI
34	MLI 25-1-2	Mali	77	UPL RI 7	IRRI
35	DKA 4	Mali	78	KALIA	IRRI
36	DKA- M8	Mali	79	IR 74371-46-11	IRRI
37	SIK 350-A-150	Mali	80	IR 74371-54-11	IRRI
38	DKA-M11	Mali	81	IR 80411-49-1	IRRI
39	DKA 22	Mali	82	IR81023-B116-1-2	IRRI
40	DKA-M9	Mali	83	WAY RAREM	IRRI
41	DKA 1	Mali	84	VANDANA	IRRI
42	DKA 21	Mali	85	IR 77298-5-618	IRRI
43	MLI 20-4-3-1	Mali	86	IR 74371-70-11	IRRI
			87	UPLRI5	IRRI

3.3 Experimental Design

The field experiment was laid out in Randomized Complete Block Design (RCBD) with three replications with 2 m separating replications. Each replication constituted eighty seven pots and each pot contained a variety. Three pots per row were separated by 0.5 m. complete randomized design was used for statistical analyses of the physico-chemical parameters.

3.4 Agronomic Practices

Soil sterilization was done by pouring a quantity of water into sterilizing container (metal drum) with a rack placed inside. A 40kg of soil sample was placed on top of the rack over the water. The soil sample was allowed to heat for about an hour until it reaches 180^{o} F. The heated soil sample was allow to cool before use. Seeds were nursed for twenty one (21) days in plastic pots. Seedlings were then transplanted in a 12 litre pots filled with 12kg of top sterilized soil each. Thinning was done two week after transplanting.

3.4.1 Fertilizer Application

Compound fertilizer, NPK (15:15:15) was top dressed at a rate of 2g per pot three (3) days after transplanting. Urea at 1.5g per pot was also top dressed at tillering and panicle initiation Stage.

3.4.2 Pest and Weed Control

Systemic pesticide Lambda Master 2.5 EC at a dosage of 100 ml per liter was applied to control pest infestation using Knapsack sprayer. Weed control in or around various pots was done manually.

3.5 Harvesting

Harvesting of rice accessions was done manually with scissors when the crop reached 80% physiological maturity period. Harvested seeds were sun dried to attained 13% moisture content level.

3.5.1 Data Collection

The following physiochemical data were collected using standard IRRI and WARDA (2007) rice descriptors.

3.5.2 Aroma

Aromatic nature of each rice genotype was measured by using Leaf Aromatic Test (LAT). 10 cm leaf sample was collected at early vegetative stage from each accession and the sample was placed in eppendorf tube. 10 ml potassium hydroxide (KOH 1.7 %) solution was pipette into the tube and covered immediately for ten minute. Aroma was determined for every sample by a panel of four people. The leaf samples were scored as (1 slightly aroma), (2 moderate aroma), (3 strong aroma) and (0 non aroma).

3.5.3 Milled Grain Length (mm)

Average 10 representative grains were randomly selected from each sample. Vernier caliper was used in measuring the gain length from glume to the apiculus of the productive palea. Based on the measured length of the grains, the milled rice grains were categorized into four groups; short (<5.5mm), medium (>5.51 <6.6), long (>6.6 <7.49mm) and extra-long (>7.5mm) (Rickman *et al.*, 2006).

3.6 Milled Grain Width (mm)

Random sample of ten (10) whole rice grains were measured using vernier caliper from the distance across the productive lemma and palea at broadest point.

3.6.1 Grain Thickness (mm)

Preferably, 10 representative whole grains, dried to 13% moisture content were measured with a vernier caliper for productive lemma and palea thickness.

3.6.2 100 Grain weight (g)

One hundred well developed, whole grains were randomly selected from each accession, dried to 13% moisture content. Weighed on a balance precision scale.

3.6.3 Length to Width ratio

The length to width ratio was determined as the measurement of the grain length upon the grain width. 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) (Rickman *et al.*, 2006).

$$\textbf{Length to width ratio} = \frac{\textbf{Average grain length, mm}}{\textbf{Average grain length, mm}} \ldots$$

3.7 Physico-chemical Data

Seed sample were sun dried to obtained 13% moisture content level for milling, sample were dehusked using THU- 34A satake husker. The brown rice obtained from the dehusking was polished in a BSO8A satake single pass friction rice pealer.

All the laboratory analysis was repeated twice for each sample.

3.7.1 Alkali Spreading Value/Gelatinization Temperature

Six (6) whole milled grains were selected and placed in glass petri dish containing 1.7% (KOH) in 10 ml of distilled. The grains were arranged with forcep to provide space among grains for dispersion. The petri dishes were concealed at room temperature for 23 hours at 30 °C in an oven or by use of ambient temperature. The sample was scored using 7 point numerical dispersion scale.

3.7.2 Elongation Ratio

Ten (10) whole milled rice grains was placed in test tubes containing 10 ml of distilled water, the samples were allowed to soaked for 30 minutes and the test tube were later placed in boiled water bath for 10 mins. After the 10 mins in water bath the water in each test tube were drained, and cooked grain were kept on a petri dish for one minute.

The length and width of each sample were measured using vernier caliper. Elongation ratio was estimated by the formula described by Sood *et al.*, (1983).

$$ER = \left(\frac{Lf}{Bf} - \frac{Lo}{Bo}\right) / \left(\frac{Lo}{Bo}\right)$$

Where, LF, BF are mean length and width of the grains after cooking

LO, BO: mean length and breadth of the grains before cooking

3.7.3 Volume Expansion Ratio (VER)

5g milled rice grain was weigh and placed in test tube with 15 mL of distilled water. The initial volume of water was measured. Samples were allowed to cocked for about 10 minutes and were later place in boiled water for 20 minutes at 80 ^{0}C. The rice samples were dipped into 50 mL water and the increase in final water volume for each sample was measured using calibrated measuring cylinder.

$$\text{Volume expansion ratio} = \frac{X-50}{Y-15}$$

Where Y is the initial volume of water, and X final volume of water.

3.8 Water Uptake (WU)

2g of rice grain were placed in 50 ML test tubes with 10mL of distilled water for 30 minutes. The rice samples were placed in boiled water bath for about 45 minutes at 80°C. Three (3) test tubes were filled with 10 mL of water as control in the water bath without rice grains. After cooling supernatant were transferred into graduated measuring cylinder and the level of water were measured. Water uptake was determined by the formula Water uptake =

$$\left(\frac{100}{2g}\right) \text{*actual water absorbed (Anon, 2004).}$$

3.8.1 Gel Consistency

15 whole milled rice grains was ground into fine powder. The sample was sieved using 100 mm sieve. 100 mg of rice sample was placed in 50 ml test tube. 0.25% thymol blue in 0.2 ml of ethanol and 2.0 mL of 11.2 g of potassium hydroxide (KOH) in 160 mL purified water. The sample was placed in boiled water bath for 8 minutes and was allowed to cool before placing them in ice bath for 20 minutes

.Sample was horizontally placed on graph sheet for an hour before measurement. The transparency of paste dissolved out of the kernels and degree of disintegration were measured (Bhattacharya, 1979).

3.8.2 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT version 11. Mean separation was carried out using least significant difference (Lsd). Correlation coefficients were estimated to assess the strength of association among the different traits.

CHAPTER FOUR

4.0 RESULTS

4.1 Volume Expansion, Water Uptake, Grain length and Width after cooked

There were highly significant (P< 0.001) differences among the accessions for volume expansion ratio, water uptake and grain length except for grain width after cooked which showed non- significant differences among the accessions studied are reported Table 4.1. FAROX-15 (2.77) exhibited the greatest volume expansion ratio followed by SBT (2.74) while the least value was recorded for variety DKA-M2 (1.01). The highest water uptake was recorded for variety PHKA RUMDON (348.74) and the lowest for DKA 21 (50.1). Variety SIK 343-A10 had the longest grain length with shortest length recorded for variety GR- 21. The largest width increase during cooking was recorded for WAB-2081-WACB-TGR-B (3.47 mm) and the lowest for TXD 88 (2.53 mm).

Table 4.1 Mean Volume Expansion Ratio, Water Uptake, Grain Length and Grain Width after Cooked of Eighty Seven Rice Accessions

Accession Name	VER	GLC	WU	GWC
WAB2081-WAC B-TGR4-B	1.84	8.70	175.64	3.47
WAB2125-WAC B-1-TGR3-WAT B1	2.49	7.70	75.86	2.73
IR 841 (CHECK)	2.21	8.63	274.44	2.97
DKA-M2	1.82	8.70	275.13	3.13
JASMINE85	1.94	8.43	250.98	2.67
FAROX 508-3-10-F43-1-1	1.40	8.43	75.18	2.80
FAROX 508-3-10-F44-2-1-1	1.10	8.57	99.92	2.60
WAB 2098-WAC2-1-TGR2-WAT B2	1.74	8.50	125.31	2.97
WAB 2056-2-FKR2-5-TGR1-B	1.21	8.77	268.98	3.13
WAB 2060-3-FKR1-WAC2-TGR4-B	1.41	8.23	49.12	2.77
TXD 88	1.52	8.07	125.39	2.53
WAB 2098-WAC3-1-TGR1-4	2.10	8.20	224.94	2.87
WAB 2076-WAC1-TGR1-B	2.39	7.50	275.19	2.70
WAB 2081-WAC2-2-TGR2-WAT B3	1.34	8.90	50.44	2.87
GBEWAA	2.16	8.23	270.69	2.90

PERFUME IRRIGATED	1.97	8.23	149.84	2.83
WAS-122-13-WAS-10-WAR	1.61	7.57	149.12	2.77
LONG GRAIN ORDINARY 2	1.76	7.87	174.87	2.77
EXBAIKA	1.59	8.43	125.32	2.73
WAS-163-B-5-3	1.48	8.53	75.84	2.93
FAROX 15	2.77	8.67	275.62	3.10
PERFUME SHORT	1.19	9.03	124.98	2.87
KATANGA	1.59	8.13	276.13	2.73
TOX 3107	1.50	8.17	176.06	3.07
ANYOFULA	2.61	8.07	300.53	2.83
NABOGU	1.89	7.97	125.67	2.67
GR 21	2.04	6.97	150.89	2.60
PHKA RUMDON	2.27	8.63	348.74	3.10
MLI 20-4-1-1-1	1.56	8.60	126.52	3.00
DKA-M2	1.02	7.77	150.46	2.77
SIK 353-A10	1.89	9.17	200.07	2.93
DK 3	2.15	8.70	125.29	3.10
MLI 6-1-2-3-2	1.30	8.13	50.08	2.90
MLI 25-1-2	1.55	8.73	124.74	3.07
DKA 4	1.45	7.80	75.92	2.63
DKA- M8	1.53	7.93	100.04	2.87
SIK 350-A-150	1.52	8.57	100.29	3.00
DKA-M11	1.16	7.97	123.64	2.77
DKA 22	1.63	7.80	75.57	2.93
DKA-M9	1.62	8.27	125.30	2.77
DKA 1	1.63	8.67	125.18	2.73
.DKA 21	1.33	8.00	50.01	2.97
MLI 20-4-3-1 SBT	1.72	8.03	74.40	2.87
70	2.74	8.33	274.94	2.90

Table 4.1 CONT'D

Accession Name	VER	GLC	WU	GWC
BASMATI 113	1.49	8.33	126.23	2.93
L50	2.04	8.03	75.55	3.03
BASMATI 123	1.50	8.07	125.05	3.07
CRI-30	1.70	8.20	145.18	2.93
CRI-2	1.61	8.73	99.51	2.97
CRI-45	1.69	8.83	98.79	2.83
CRI-73	1.82	8.10	124.29	2.77
CRI-48	2.31	8.40	199.24	3.20
NERICA 1	1.37	8.07	74.24	2.70
AFRK-7	1.57	8.30	75.47	3.07
AFRK-8	2.61	8.10	123.99	2.83
AFRK-5	1.44	8.47	124.97	2.97
AFRK 13	1.49	8.33	124.48	2.87
NERICA-4	1.44	8.43	50.13	3.00

AFRK-6	1.60	8.03	124.43	2.60
AFRK-11	1.37	9.00	99.61	2.80
NERICA 14	1.90	8.27	175.04	2.73
AFRK-9	1.87	7.77	124.13	3.10
AFRK-3	1.47	8.47	76.02	2.90
AFRK-1	1.80	8.20	251.63	2.93
AFRK-10	1.24	8.37	125.43	2.77
AFRK-12	1.57	8.30	101.10	2.87
AFRK-4	1.95	8.10	224.32	2.77
IR 74963-2-6-5-1-3-3	1.16	8.33	225.42	2.80
IR 81412-B-B-82-1	1.61	8.50	200.75	2.87
IR 55419-04	2.16	8.43	299.35	2.80
IR 79913-B-179-B-4	1.19	7.60	75.20	2.80
APO	2.68	8.23	76.41	2.87
N22	1.52	8.33	76.56	2.90
IR 77298-14-1-2-10	1.75	7.70	124.68	2.80
KALIAUS	1.66	8.70	225.32	2.93
UPLRI7	1.82	8.63	200.10	2.90
KALIA	1.52	7.57	99.46	2.73
IR 74371-46-1-1	2.05	7.97	125.12	2.73
IR 74371-54-1-1	1.93	9.07	124.64	3.03
IR 80411-49-1	1.42	8.73	275.63	2.97
IR81023-B-116-1-2	2.19	8.23	251.47	2.97
WAYRAREM	2.39	7.80	199.74	2.97
VANDANA	1.63	8.40	148.21	2.93
IR 77298-5-6-18	1.48	7.63	84.32	2.90
IR 74371-70-1-1	2.60	8.10	148.44	2.93
UPLR 15	2.73	8.77	50.39	2.93
CV (%)	18.6	6.60	0.80	8.10
LSD(P<0.005	0.53	0.54	1.95	0.37

4.2 Length of Blue Gel, Gel Consistency and Elongation Ratio.

Data analyzed regarding length of blue, gel consistency and elongation ratio are reported in Table 4.2. The result showed highly significant (P<0.001) differences among the various accessions for length of blue gel and elongation ratio. Among the varieties studied, 22 % recorded medium gel, 71 % obtained hard gel while only 7 % of the samples were soft. Highest blue gel level was exhibited in variety DKA-M9 and the lowest in MLI 20-4-3-1. Variety WAB 2125- WAC B- TGR3- WAT B1 obtained the least elongation ratio value of 1.1, while maximum elongation ratio was recorded for IR 74371-54-1-1 (1.7).

Table 4.2 Mean Length of Blue Gel, Gel Consistency and Elongation Ratio of Eighty Seven (87) Rice Accessions

Accession Name	LBG	GC	ELR
WAB2081-WAC B-TGR4-B	27.6	H	1.2
WAB2125-WAC B-1-TGR3-WAT B1	29.6	H	1.1
IR 841 (CHECK)	30.0	H	1.4
DKA-M2	40.3	M	1.4
JASMINE85	61.6	S	1.2
FAROX 508-3-10-F43-1-1	30.7	H	1.2
FAROX 508-3-10-F44-2-1-1	57.3	S	1.3
WAB 2098-WAC2-1-TGR2-WAT B2	31.7	H	1.3
WAB 2056-2-FKR2-5-TGR1-B	30.7	H	1.4
WAB 2060-3-FKR1-WAC2-TGR4-B	44.7	M	1.1
TXD 88	28.3	H	1.3
WAB 2098-WAC3-1-TGR1-4	28.8	H	1.2
WAB 2076-WAC1-TGR1-B	29.3	H	1.2

WAB 2081-WAC2-2-TGR2-WAT B3	33.0	H	1.2
GBEWAA	46.7	M	1.3
PERFUME IRRIGATED	28.7	H	1.2
WAS-122-13-WAS-10-WAR	29.3	H	1.2
LONG GRAIN ORDINARY 2	30.0	H	1.1
EXBAIKA	44.3	M	1.3
WAS-163-B-5-3	29.7	H	1.3
FARO 15	29.3	H	1.3
PERFUME SHORT	31.7	H	1.3
KATANGA	28.3	H	1.3
TOX 3107	29.3	H	1.1
ANYOFULA	44.0	M	1.1
NABOGU	44.0	M	1.3
GR 21	28.6	H	1.3
PHKA RUMDON	30.3	H	1.2
MLI 20-4-1-1-1	30.0	H	1.2
DKA-M2	47.3	M	1.2
SIK 353-A10	41.0	M	1.3
DK 3	29.0	H	1.4
MLI 6-1-2-3-2	29.6	H	1.2
MLI 25-1-2	30.6	H	1.3
DKA 4	44.0	M	1.3
DKA- M8	38.6	H	1.3
SIK 350-A-150	30.3	H	1.5
DKA-M11	44.6	M	1.1
DKA 22	31.0	H	1.1
DKA-M9	60.0	S	1.3
DKA 1	29.3	H	1.2
DKA 21	46.6	M	1.2
MLI 20-4-3-1 SBT	27.6	H	1.1
70	35.6	H	1.1

Table 4.2 OCNT'D

Accession Name	LBG	GC	ELR
BASMATI 113	59.3	S	1.1
L50	30.0	H	1.2
BASMATI 123	29.0	H	1.3
CRI-30	31.6	H	1.2
CRI-2	30.6	H	1.2
CRI-45	46.6	M	1.1
CRI-73	30.3	H	1.3
CRI-48	30.0	H	1.3
NERICA 1	32.0	H	1.2
AFRK-7	35.0	H	1.2
AFRK-8	33.6	H	1.3
AFRK-5	28.6	H	1.3
AFRK 13	45.6	M	1.2
NERICA-4	46.0	M	1.3
AFRK-6	31.6	H	1.2
AFRK-11	28.3	H	1.2
NERICA 14	64.0	S	1.1

AFRK-9	31.6	H	1.2
AFRK-3	30.6	H	1.3
AFRK-1	36.0	H	1.1
AFRK-10	33.6	H	1.1
AFRK-12	33.0	H	1.3
AFRK-4	32.0	H	1.3
IR 74963-2-6-5-1-3-3	31.0	H	1.3
IR 81412-B-B-82-1	30.3	H	1.2
IR 55419-04	31.0	H	1.4
IR 79913-B-179-B-4	31.3	H	1.2
APO	33.3	H	1.3
N22	43.0	M	1.4
IR 77298-14-1-2-10	31.6	H	1.3
KALIAUS	44.0	M	1.3
UPLRI7	44.3	M	1.4
KALIA	60.0	S	1.2
IR 74371-46-1-1	29.6	H	1.4
IR 74371-54-1-1	28.6	H	1.7
IR 80411-49-1	29.3	H	1.3
IR81023-B-116-1-2	30.3	H	1.4
WAYRAREM	30.6	H	1.2
VANDANA	41.6	M	1.2
IR 77298-5-6-18	36.6	H	1.2
IR 74371-70-1-1	29.6	H	1.3
UPLR 15	46.0	M	1.4
CV (%)	13.0		10.4
Lsd(P<0.005)	**7.4**		**0.2**

4.3 Alkaline Spread Value, Gelatinization Temperature, Aroma and 100 Grain Weight.

The results of alkaline spread value , gelatinization temperature, aroma and one hundred grain weight are presented in Table 4.3 .Analysis of variance shows highly significant (p<0.001) differences exist amongst all the varieties for 100 grain weight. Amongst the 87 varieties studied 30 were aromatic while 57 were non aromatic with 66% .GT of rice accessions were classified as low (55-69), intermediate (70-74) and high (>74). 64 % of the rice samples were intermediate, 20 % low and 16 % shows high Gelatinization temperature. Amongst accessions studied CRI-2 exhibited the greatest 100 grain weight and the least was recorded for variety N22.

Table 4.3 The Alkaline Spreading Value (ASV), Gelatinization Temperature (GT), 100 Grain Weight and Aroma of Eighty Seven (87) Rice Accessions

Accession Name	ASV	GT	100GW	AR
WAB2081-WAC B-TGR4-B	6(H)	L(55-69)	3.3	AS
WAB2125-WAC B-1-TGR3-WAT B1	5(I)	I(70-74)	3.2	P
IR 841 (CHECK)	6(H)	L(55-69)	2.8	P
DKA-M2	6(H)	L(55-69)	2.6	AS
JASMINE85	5(I)	I(70-74)	2.7	P
FAROX 508-3-10-F43-1-1	3(L)	I(70-74)	2.7	AS
FAROX 508-3-10-F44-2-1-1	2(L)	H.>74	2.2	AS
WAB 2098-WAC2-1-TGR2-WAT B2	4(I)	L(55-69)	3.0	P
WAB 2056-2-FKR2-5-TGR1-B	3(L)	I(70-74)	2.9	AS
WAB 2060-3-FKR1-WAC2-TGR4-B	3(L)	I(70-74)	2.9	P
TXD 88	4(I)	I(70-74)	2.4	AS
WAB 2098-WAC3-1-TGR1-4	6(H)	L(55-69)	2.9	P
WAB 2076-WAC1-TGR 1-B	7(H)	L(55-69)	2.6	AS
WAB 2081-WAC2-2-TGR2-WAT B3	3(L)	I(70-74)	3.0	AS
GBEWAA	5(I)	I(70-74)	2.7	P
PERFUME IRRIGATE	5(I)	I(70-74)	2.7	P
WAS-122-13-WAS-10-WAR	3(L)	I(70-74)	2.7	AS
LONG GRAIN ORDINARY 2	2(L)	H>74	3.0	AS

EXBAIKA	6(H)	L(55-69)	2.7	AS
WAS-163-B-5-3	2(L)	H>74	2.5	AS
FARO 15	7(H)	L(55-69)	3.5	P
PERFUME SHORT	6(H)	L(55-69)	2.9	P
KATANGA	3(L)	I(70-74)	2.5	P
TOX 3107	2(L)	H>74	2.5	P
ANYOFULA	4(I)	I(70-74)	3.3	P
NABOGU	4(I)	I(70-74)	2.5	P
GR 21	4(I)	I(70-74)	2.2	AS
PHKA RUMDON	6(H)	L(55-69)	2.8	AS
MLI 20-4-1-1-1	4(I)	I(70-74)	3.3	AS
DKA-M2	3(I)	I(70-74)	2.4	AS
SIK 353-A10	6(H)	L(55-69)	2.8	AS
DK 3	5(I)	I(70-74)	2.9	AS
MLI 6-1-2-3-2	5(I)	I(70-74)	2.5	AS
MLI 25-1-2	3(L)	I(70-74)	3.0	P
DKA 4	4(I)	I(70-74)	2.5	AS
DKA- M8	3(L)	I(70-74)	2.8	AS
SIK 350-A-150	3(L)	I(70-74)	2.6	AS
DKA-M11	3(L)	I(70-74)	2.8	AS
DKA 22	4(I)	I(70-74)	2.9	AS
DKA-M9	4(I)	I(70-74)	2.3	AS
DKA 1	3(L)	I(70-74)	2.8	AS
.DKA 21	4(I)	I(70-740	3.3	AS
MLI 20-4-3-1	2(L)	I(70-74)	2.7	P
SBT 70	6(H)	L(55-69)	3.6	P

Table 4.3 CONT'D

Accession Name	ASV	GT	100GW	AR
BASMATI 113	5(I)	I(70-74)	2.9	P
L50	5(I)	I(70-74)	3.3	P
BASMATI 123	6(H)	L(55-69)	2.9	P
CRI-30	4(I)	I(70-74)	2.9	AS
CRI-2	4(I)	I(70-74)	4.1	AS
CRI-45	3(L)	H>74	3.9	AS
CRI-73	4(I)	I(70-74)	3.2	AS
CRI-48	5(I)	I(70-74)	2.9	P
NERICA 1	5(I)	I(70-74)	2.9	AS
AFRK-7	5(I)	I(70-74)	2.8	AS
AFRK-8	5(I)	I(70-74)	2.9	P
AFRK-5	5(I)	I(70-74)	3.2	P
AFRK 13	3(L)	H>74	2.6	AS
NERICA-4	4(I)	I(70-74)	2.9	AS
AFRK-6	3(L)	H>74	3.2	AS
AFRK-2	3(L)	H>74	3.5	P
AFRK 11	4(I)	I(70-74)	3.2	P
NERICA 14	4(I)	I(70-74)	3.3	p
AFRK-9	3(L)	H>74	3.0	P
AFRK-3	3(L)	H>74	2.8	AS

AFRK-1	3(L)	H>74	2.9	P
AFRK-10	4(I)	I(70-74)	3.5	AS
AFRK- 12	4(I)	I(70-74)	2.8	AS
AFRK-4	3(L)	H>74	2.5	AS
IR 74963-2-6-2-5-1-3-3	2(L)	H>74	2.8	AS
IR 81412-B-B-82-1	4(I)	I(70-74)	2.9	AS
IR 55419-04	5(I)	I(70-74)	2.7	AS
IR 79913-B-179-B-4	4(I)	I(70-74)	2.8	AS
APO	6(H)	I(70-74)	3.3	AS
N22	3(L)	I(70-74)	1.8	AS
IR 77298-14-1-2-10	4(I)	I(70-74)	2.8	P
KALIAUS	4(I)	I(70-74)	2.4	AS
UPLRI 7	7(H)	L(55-69)	2.8	AS
KALIA	4(I)	I(70-74)	2.6	AS
IR 74371-46-1-1	7(H)	L(55-69)	2.5	AS
IR 74371-54-1-1	7(H)	L(55-69)	2.5	AS
IR80411-49-1	5(I)	I(70-74)	2.9	AS
IR81023-B-116-1-2	6(H)	L(55-69)	2.6	AS
WAYRAREM	4(I)	I(70-74)	2.9	P
VANDANA	4(I)	I(70-74)	2.5	AS
IR 77298-5-6-18	4(I)	I(70-74)	2.6	AS
IR74371-70-1-1	6(H)	L(55-69)	2.5	AS
UPLRI 15	3(L)	H>74	2.6	AS

4.4 Correlation Analysis of Physico – Chemical Parameters

Linear correlation coefficients among some quality characters of grain rice are presented in Table 4.5. Alkaline spread value was significant strong correlated (r =1.00 ^{xxx}) with gelatinization temperature, water uptake (r = 0.27 ^{xxx}) but significant negatively correlated with gel consistency, volume expansion ratio and elongation ratio respectively. Elongation ratio recorded non-significant correlation with water uptake (r = 0.02^{ns}) and gelatinization temperature (r = 0.09 ^{ns}) except with grain length (r = 0.76 ***) and grain length after cooked (r = 0.49***) which revealed significant weak correlation between these traits. Gel consistency exhibited significant negative correlations with volume expansion ratio (r = -0.13*).

Table 4.4 Correlation Coefficients among Various Physiochemical Parameters

	ASV	ELR	GC	GL	GLAC	GT	GTN	GW	GWAC	VER	WU
ASV	-										
ELR	0.09ns	-									
GC	-0.10ns	0.01ns	-								
GL	-0.05ns	0.76***	-0.03ns	-							
GLAC	0.08ns	0.49**	-0.04ns	0.17**	-						
GT	1.00***	0.09ns	-0.10ns	-0.05ns	0.08ns	-					
GTN	0.01ns	-0.12ns	0.02ns	0.17**	0.03ns	0.10ns	-				
GW	0.08ns	0.06ns	-0.07ns	-0.09ns	-0.04ns	0.08ns	0.01ns	-			
GWAC	0.09ns	0.16ns	-0.05ns	-0.01ns	0.28***	0.09ns	0.02ns	0.07ns	-		
VER	0.33ns	0.08ns	-0.13*	-0.06ns	0.04ns	0.33***	0.01ns	0.10ns	0.04ns	-	
WU	0.27***	0.02ns	-0.13*	0.01ns	0.07ns	0.27***	0.02ns	-0.05ns	0.09ns	0.35***	-

*, ** and*** significant at 0.05, 0.01 and 0.001 probability levels respectively, ns = non-significant,ASV= Alkaline spreading value,ELR=Elongation Ratio,GC= Gel Consistency,GLAC= Grain Length After Cooked,GT=Gelatinization Temperature, GTN= Grain Thickness,GW = Grain Width,GWAC = grain Width After Cooked,VER= Volume Expansion Ratio and WU= Water Up take

4.5 Grain Dimension.

Over 50 % 0f the accessions were classified as medium, 36. 7 % as long grain while 7 % were classified as short. 63.2 % were classified as medium and 37 % as board with respect to grain width Figure 4.1.

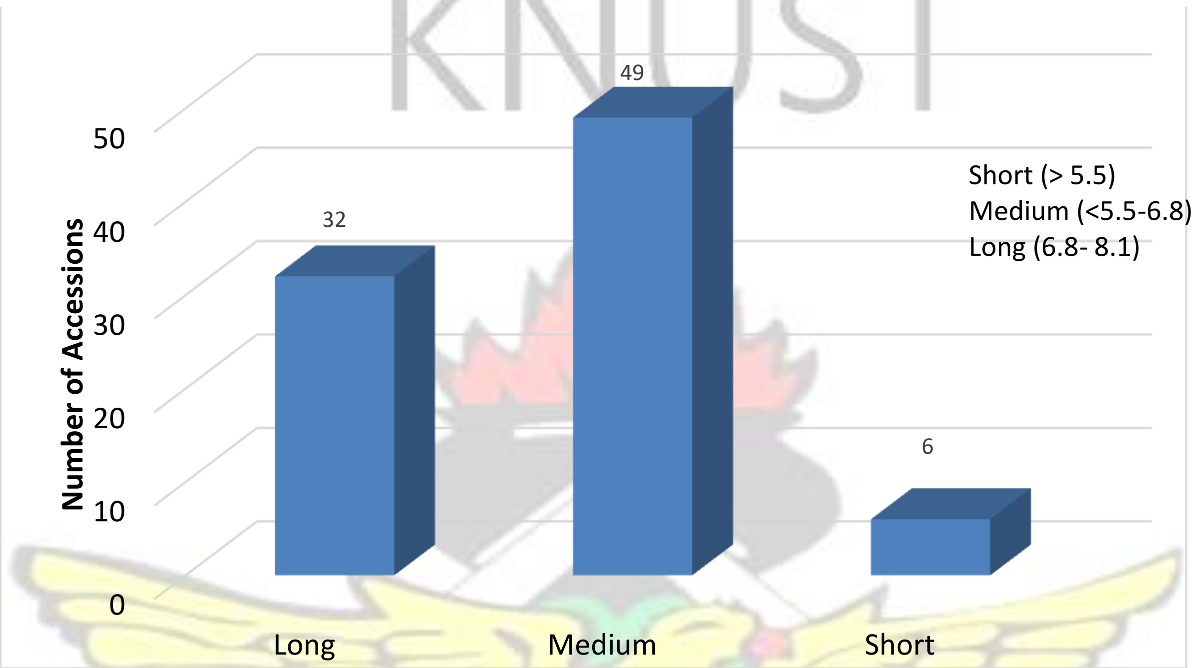

Figure 4.1 Grain Length distribution of rice accessions.

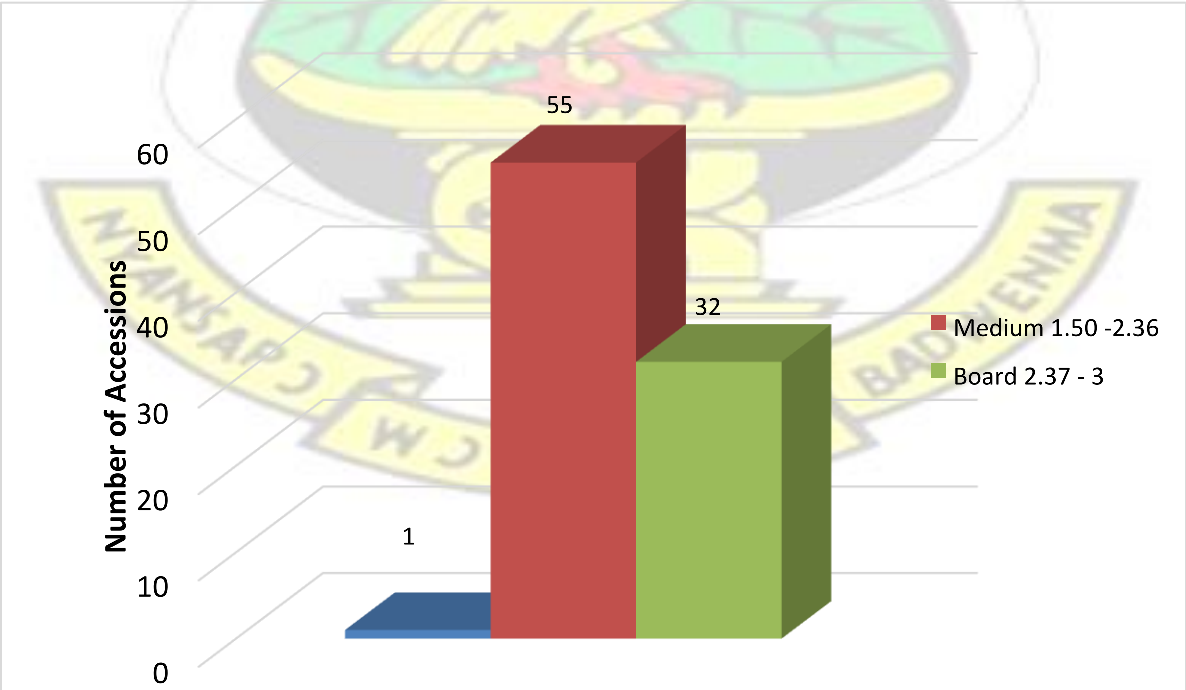

Figure 4.2 Grain Width distribution

4.6 Length/Breadth Ratio

Figure 4.3 shows the results of length and breadth ratio. Amongst the 87 accessions studied, 52% where medium, 38% slender while only 10 % were bold.

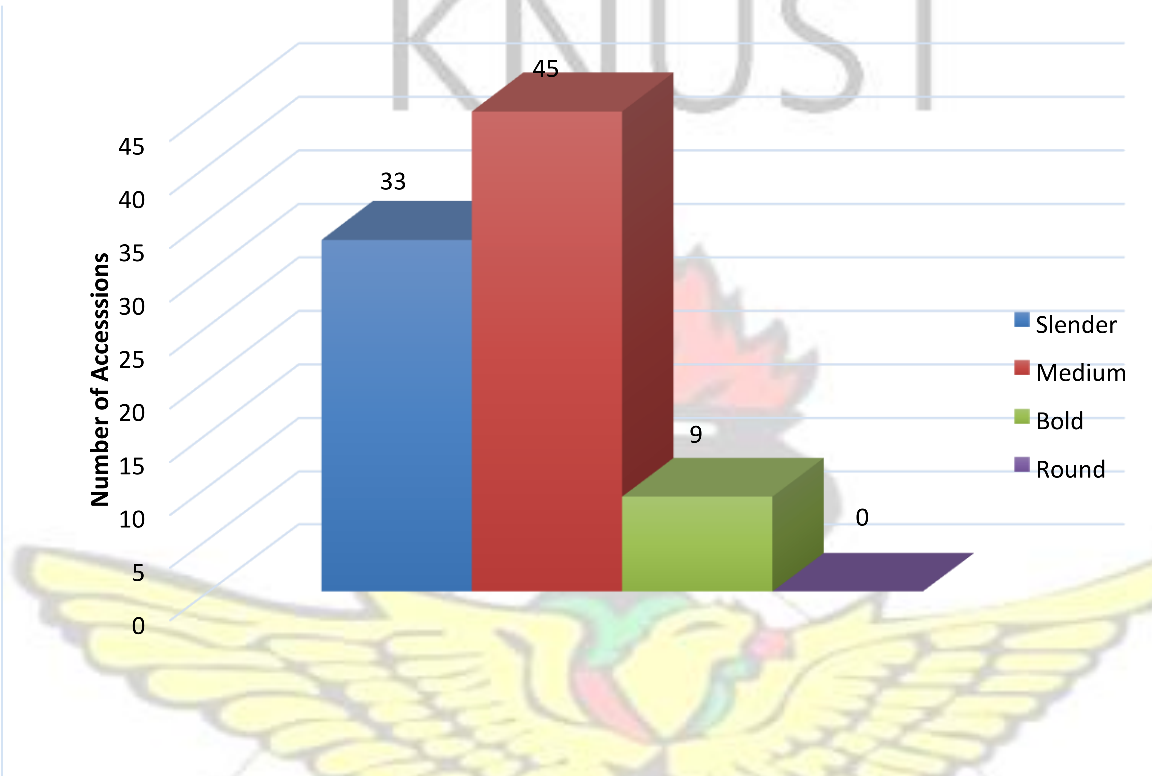

Figure 4.3 L/W Ratio distribution

CHAPTER FIVE

5.0 DISCUSSION

Quality of rice grains depends on their physicochemical characteristics which are influenced by the character of the plant genotype (Kishine *et al.*, 2008). The cooking and eating rice characteristics is the basic choice for consumers. Size and shape of grains are among the first quality criteria breeders considered in development new cultivars, preferences for size and shape of grains vary from one batch to another (Rani *et al.,* 2006).This study was conducted to assess grain quality of eighty seven (87) rice accessions. The results from various traits studied are discussed below.

5.1 Grain Length and Width

Since rice is produced marketed according to grain size and shape, determining the physical dimensions of the varieties are very important. Grain size in breeding applications is usually assessed by the grain weight, which is positively correlated with several characters including grain length, grain width and grain thickness, (Xu *et al.*, 2002). The coefficient of variation for grain length and width were 7.9% and 2.25 % respectively. The length grain ranged from 5.47-8.03 mm with a mean value of 6.67 mm and width from 1.60 to 2.73 mm and a mean of 2.25 mm. Although the length and width of the grains are varietal properties, environmental conditions during their growth might affect these traits (Irshad, 2001). The minimum grain length was recorded in variety IR 74371-54-1-1 while maximum exhibited in variety CRI- 45. A similar finding was obtained by Yadav *et al.* (2007). Short and medium rice grains are used in making porridge, while broken grain is used for fried rice. Long and slender shapes have the highest premium and are used with sauces to prepare jollof or fried rice (Takoradi 2008). Even though the preference of rice grain characteristics vary with different consumer groups, long and slender rice is mostly favored by many consumers in the world and are good valuable attributes that could be exploited in breeding to improve the grain characteristics of local rice varieties.

5.2 100 Grain Weight

100 grain weight is an important parameter in grain quality, it‟s provides information about grain density and it size. The co-efficient of variation and standard deviation values were 8.6 % and 0.20 respectively. The result conformed to the result obtained by Ali *et al. (2*000) who detected similar variation for 100 grain weight. The weight of rice grains can vary considerably with moisture content, fertilizer treatment, weather conditions and the type of soil where the rice is grown. These variations for 100 grain weight were due to different grain size and grain shape of the accessions used. Long and slender grains generally have lower grain weight than medium and bold grains. Richman *et al.* (2006) reported that grain of diverse density mill differently, and are possible to cook and retain moisture differently. High grain weight will increase seed emergence, tillering, density, spikelet and yield (Noor- Mohammadi *et al.*, 2000). The long grain and translucent types could be used in grain quality development to meet the consumers‟ preference.

5.2.1 Grain Length and Width after Cooking

Rice grains absorb water and increase in volume through increase in length or width during cooking (Hogan and Plank, 1958). Length wise increase without increase in girth is desirable characteristics in high quality premium rice (Hossain *et al.*, 2009). Analysis of variance revealed highly significant ($P<0.001$) differences among the accessions for grain length after cooked except for grain width which noted nonsignificant differences among the varieties. In this study, length of the cooked ranged from 6.97 -9.13 mm with a mean value of 8.28 mm and the width after cooked from

2.53 – 3.47 mm. The longest length after cooked was recorded for variety SIK-353-A 10 and the lowest noted for GR-21. The longest width increase during cooking was recorded in WAB-2081-WAC B-TGR4- B (3.47 mm) and the lowest for TXD 88 (2.53 mm) (Table 4.2). High expansion breadth wise is not a desirable quality attributes in high quality rice required to command premium in the market. This result is contrary to the report of Hossain *et al*. (2009) who reported kernel length after cooking of some hybrids rice ranging from 8.84 to12.73 mm and 10.20 to 12.40 mm.

5.2.2 Elongation Ratio and Length/Breadth Ratio

Higher elongation ratio of cooked rice is preferred by the consumer than that with lower elongation ratio (Shahidullah *et al*., 2009). Among the varieties, the elongation ratio ranged from 1.09 to 1.67. The coefficient of variation for elongation ratio and length/breadth were 10.4 % and 13.3 % respectively. The variation may be attributed to the different grains size and shape of the accessions used. This result is contrary to the earlier findings of Yadav *et al.* (2007) who observed no significant differences among different rice varieties for elongation ratio. Kernel shape and L/B ratio are important features for grain quality assessment (Rita and Sarawgi, 2008). Among the varieties studied, the L/B ratio ranged from 2.15-4.5.The variety IR 81412-B-B-82-1 recorded the highest L/B ratio and the least was found in variety GR 21. Based on the L/B ratio, the rice samples were classified into three different categories, 33 of the varieties were slender in size, 45 medium and 9 bold (Figure 4.3).The result is in lined with the finding of Shilpa (2010). Certain accessions which elongate more than others upon hydration and starch gelatinization without increase in girth are considered desirable cooking quality traits in most high quality rice in the world.

5.2.3 Volume Expansion and Water up Take Value

During cooking process of rice, grains absorb water and increase in volume through increase in length or breadth. The Coefficients of variation for volume expansion ratio and water uptake values were 18.6 % and 0.8 % respectively. Water uptake showed positive weak correlation with volume expansion ratio. Variety DKA recorded minimum volume expansion ratio, while the maximum was exhibited for variety FAROX 15 (Table 4.1). The maximum water uptake was recorded in variety PHKA RUMDOM, while variety DKA had the lowest. The variation in these traits may be attributed to drying methods and genotype used. In this study it was observed that short and medium grain varieties have higher water absorption than long grain types. The result is contrary to Shilpa. (2010) findings, who observed Water uptake value ranges from 175 to 275 respectively. Shahidullah *et al.* (2009) reported that lower volume expansion ratio is preferred by consumers than higher volume expansion ratio. Tan *et al*. (2000) reported that the quantity of water uptake during cooking process is associated with the appearance of cooked rice.

5.2.4 Alkaline spread value and Gelatinization Temperature

The time required for cooking is determined by the gelatinization temperature (GT). Gelatinization temperature of rice are grouped into three classes low ranging from (55-69), Intermediate which means the temperature required for normal cooking time is (70-74) and High GT (>74) (Cruz and Khush, 2000). The alkali spreading value (ASV) and gelatinization temperature (GT) were calculated for all the rice varieties examined. Among the varieties studied 64 % were intermediate, 20 % low and 16 % of the samples recorded high GT. Varieties with low GT crumbles completely in 1.7 percent KOH solution, while varieties with intermediate GT showed incomplete fragmentation. Rice with high GT remains generally unaffected in alkali solution. In addition, the disintegration of rice starch granules is affected by the fine structure of amylopectin (Juliano, 1979). Rice with high GT remains largely unaffected in alkali solution. Low ASV and high GT were detected in FARDX 508-3-10-F44-2-1, LONG GRAIN ORDINARY2, CRI-45, AFRK-6, AFRK-2, AFRK-3, AFRK-9, AFRK-4, IR74371-2-6-2-5-1-3-3 and TOX 3107. Also high ASV and low GT were recorded in FARO-15,EXBAIKA, PERFUME SHORTPHKA-RUMDON, SIK 353-A10, IR81023-B-116-1-2, IR 74371-5-6-18, IR 74371-46-1-1,IR 74371-46-1-1, APO, SBT 70,BASMATI-123, WAB 2081-WAC-B-TGRK-B, IR 841(CHECK), DKA-M2, and WAB-2098-WAC 3-1-TGR-1-4 Table 4.4. This result is in line with the findings of Shiplap. (2010). Kurasawa *et al*. (1963) reported that gelatinization temperature influence the cooking time of rice and samples with high gelatinization temperature generally require more minutes to cook than samples with lower values GT. It also showed opposite trend probably due to genetic variability among the varieties studied.

5.2.5 Gel Consistency and Aroma

Gel consistency is a measure of cold past viscosity of milled cooked rice flour, is a good index of cooked rice texture, especially among rice of high amylose content (Tang, 1991). Rice differs in gel consistency from soft to hard (Cagampang *et al*., 1973; juliano 1979). On gel consistency basis all varieties were categorized into soft gel (61-100), medium gel (41-60) and hard gel (26- 40). The coefficient of variation and less significant different were 13 % and 7.41 respectively. In this studies 22 varieties recorded medium gel, 6 varieties were soft gel and 63 varieties recorded hard gel. The low gel consistency level might be due to the characteristics hard gel nature of the accessions used. This result is contrary to the report of shilpa *et al*. (2010). Among the accessions observed the length of blue gel was highest in DKA-M9 and lowest in MLI 20-4-3-1. Aroma is another important trait and this attribute in rice has high demand in the market. The varieties studied during this investigation showed the presence of aroma in 30 accessions with 34 %, while 57 varieties were non aromatic with 66 %. This may be due to their genetic makeup of materials used. Sarawagi *et al*. (2013) reported that qualitative traits are genetically control, thus are less influence by environmental conditions. The attractiveness of fragrance has resulted in strong human preference and selection for this trait. These varieties could be exploited in breeding programmes for their aromatic nature.

5.2.6 Correlation among some Physicochemical Properties of rice grain

Correlation analysis helps the plant breeder during selection. It can also be used as a key for indirect selection. The results of correlation analysis showed that alkaline spread value has significant strong correlation with gelatinization temperature(r = 1.00***), this mean an increase in one trait resulted to increase in the opposite traits. Alkaline spread value and gel consistency exhibited non-significant correlation among them (Table 4.4). This result agreed with earlier findings of Sagar *et al.* (1988). Elongation ratio recorded non-significant correlation with water uptake (r = 0.02^{ns}) and gelatinization temperature (r = 0.09^{ns}) except with grain length (r = 0.76 ***) and grain length after cooked (r = 0.49***) which revealed significant weak correlation between these traits. Gel consistency exhibited significant negative correlations with volume expansion ratio (r = -0.13*) it mean that increase in one trait resulted to decrease in the opposite trait. Gel consistency and gelatinization temperature exhibited non-significant correlation among them. This result agreed with findings of Sagar *et al*. (1988) who reported non- significant correlations among gel consistency and gelatinization temperature. Grain length recorded significant weak correlations with grain length after cook (r = 0.17**) and grain thickness (r = 0.17**).

Grain length after cooked and grain width after cooked also exhibited significant weak correlation among themselves. This study is in agreement with Danbaba *et al.* (2011).

Positive weak correlation was observed between Gelatinization temperature, volume expansion ratio (r = 0.33***) and water uptake (r = 0.27 ***). Volume expansion ratio and water uptake value also exhibited significant weak correlations at 1% ($p < 0.001$).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

- The result of this study showed that FARO-15 and PHKA-RUMDON had significant cooking and eating quality than all other varieties evaluated, indicating that there would be high demand for these varieties in the market.
- CRI-45 and TXD-88 exhibited the highest grain length and width, and IR 841 (Check), Basmati 113, L5O, Basmati 123, Perfume Short, Jasmine 85, Perfume Irrigated, Afrk- 10, GR 21, and Cri-30 were highly aromatic, thus consumers would prefer such varieties.
- The result also indicates that about 64% of the rice accessions were intermediate, 20% gelatinization temperature (low) and 16% gelatinization temperature (high).
- Among the varieties evaluated, CRI-2 scored the highest 100 grain weight and could be useful in breeding programmes in order to improve rice yield.

6.2 RECOMMENDATIONS

- Based on the above findings, it is recommended that varieties such as CRI- 45 and TXD- 88 should be incorporated into rice breeding programmes for improvement of grain quality traits.
- It is also recommended that FARO-15 and PHKA- RUMDON varieties should be incorporated in breeding programmes due to their good cooking and eating characteristics.

- Highly aromatic varieties obtained in this study should be used in rice hybridization programmme or put through seed increase and released to farmers.

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APPENDIX

Appendix 1

Analysis of variance for Some Physico- chemical parameters

Variate: Alkaline spread value

Source of Variation	df	ss	ms	vr	Fpr.
Trt	86	406.4215	4.7258	5.18	< .001
Residual	174	158.6667	0.9119		
Total	260	565.0881			

Variate: 100 grain weight

Source of Variation	df	ss	ms	vr	Fpr.
Trt	86	34.69483	0.40343	6.67	< .001
Residual	174	10.52007	0.06046		
Total	260	45.21490			

Variate: Elongation ratio

Source of Variation	df	ss	ms	vr	Fpr.
Trt	86	2.51742	0.40343	1.73	0 .001
Residual	174	2.93918	0.01689		
Total	260	5.45660			

Variate: Gel consistency

Source of Variation	df	ss	ms	vr	Fpr.
Trt	86	19169.79	222.90	10.53	<.001
Residual	174	3682.00	21.16		
Total	260	22851.79			

Variate: Grain length after cooked

Source of Variation	df	ss	ms	vr	Fpr.

Trt	86	41.2874	0.4801	1.64	0 .004
Residual	174	51.7067	0.2972		
Total	260	92.9941			

Variate: Grain width

Source of Variation	df	ss	ms	vr	Fpr.
Trt	86	16.36803	0.19033	3.82	<.001
Residual	174	8.66673	0.04981		
Total	260	25.03477			

Variate: Grain width after cooke d

Source of Variation	df	ss	ms	vr	Fpr.
Trt	86	6.08743	0.07078	1.32	0.065
Residual	174	9.36000	0.05379		
Total	260	15.44743			

Variate: Length to width ratio

Source of Variation	df	ss	ms	vr	Fpr.
Trt	86	59.6491	0.6936	4.26	<.001
Residual	174	28.3257	0.1628		
Total	260	87.9748			

Variate: Volume expansion ratio

Source of Variation	df	ss	ms	vr	Fpr.
Trt	86	46.2973	0.5383	5.02	<.001
Residual	174	18.6751	0.1073		
Total	260	64.9724			

Appendix 2 Some Physical Parameters

Accession Name	Gl	Gw	Lbr	Accession Name	Gl	Gw	LBr
WAB 2081-WAC B-TGR4-B	7.43	2.63	2.83	SBT 70	7.40	2.20	3.36
WAB 2125-WAC B-1-TGR3-WAT B1	7.23	2.37 2.20	3.06	BASMATI 113	6.60 7.13	2.27	2.93
IR 841 (CHECK)	6.27	2.20	2.85	L5O	6.33	2.00	3.69
DKA-M2	6.43	2.30	2.93	BASMATI 123	6.90	2.10	3.03
JASMINE85	7.13	2.27	3.14	CRI-30	7.57	2.50	2.76
FAROX 508-3-10-F43-1-1	6.97	1.83	3.06	CRI-2	8.03	2.33	3.26
FAROX 508-3-10-F44-2-1-1	6.27	2.07	3.42	CRI-45	6.57	2.30	3.54
WAB 2098-WAC2-1-TGR2-WAT B2	6.57	2.30	3.19	CRI-73	6.60	2.43	2.70
WAB 2056-2-FKR2-5-TGR1-B	6.43	2.27	2.83	CRI-48	6.70	2.43	2.73
WAB 2060-3-FKR1-WAC2-TGR4-B	7.27	2.73	3.24	NERICA 1	7.23	2.37	2.85
TXD 88	6.53	1.73 2.43	2.39	AFRK-7	6.33 6.80	2.23	3.27
WAB 2098-WAC3-1-TGR1-4	6.83	2.17	3.94	AFRK-8	6.90	2.53	2.53 2.84
WAB 2076-WAC1-TGR1-B	6.43	1.70	2.65	AFRK-5	6.63	2.40	2.92
WAB 2081-WAC2-2-TGR2-WAT B3	7.40	2.33	3.42	AFRK-13	6.93	2.37	2.93
GBEWAA	6.60	2.27	3.98	NERICA 4	6.43	2.27	3.79
PERFUME IRRIGATED	6.70	1.50	2.87	AFRK-6	6.83	1.83	2.72
WAS-122-13-WAS-10-WAR	6.40		2.82	AFRK-2		2.37	2.71
LONG GRAIN ORDINARY 2	6.97		4.63	AFRK-11		2.50	

ACCESSION NAME	GL	GW	Lbr	ACCESSION NAME	GL	GW	LBR
EXBAIKA	6.57	2.40	2.74	NERICA 14	7.27	2.50	2.91
WAS-163-B-5-3	6.40	2.00	3.32	AFRK-9	6.43	2.53	2.54
FARO 15	6.53	2.30	3.12	AFRK-3	6.57	2.33	2.82
PERFUME SHORT	6.73	1.70	3.96	AFRK-1	7.20	2.23	3.28
KATANGA	6.33	2.17	2.94	AFRK-10	7.27	2.37	3.09
TOX 3107	6.93	2.07	3.36	AFRK-12	6.27	2.27	2.76
ANYOFULA	7.43	2.50	2.97	AFRK- 4	6.40	2.30	2.85
NABOGU	6.30	2.27	2.79	IR 74963-2-6-2-5-1-3-3	6.87	2.37	2.89
GR 21	5.43	2.53	2.15	IR 81412-B-B-82-1	7.23	1.60	4.52
PHKA RUMDON	7.17	1.70	4.22	IR 55419-04	6.10	2.30	2.66
MLI 20-4-1-1-1	7.33	2.63	2.82	IR 79913-B-179-B-4	6.17	2.47	2.50
DKA-M2	6.30	1.70	3.71	APO	6.30	2.47	2.56
SIK 353-A10	6.97	2.30	3.06	N22	6.03	2.43	2.60
DK 3	6.37	2.30	2.78	IR 77298-14-1-2-10	5.93	2.53	3.34
MLI 6-1-2-3-2	6.80	2.23	3.11	KALIAUS	6.97	2.30	3.04
MLI 25-1-2	6.67	2.27	2.93	UPL RI 7	6.30	2.37	2.66
DKA 4	5.83	2.13	2.79	KALIA	6.57	2.30	2.93

DKA- M8	6.33	2.33	2.74	IR 74371-46-1-1	5.87	2.37	2.50
SIK 350-A-150	5.73	2.17	2.67	IR 74371-54-1-1	5.47	2.47	2.25
DKA-M11	7.13	1.93	3.73	IR 80411-49-1	6.67	2.43	2.74
DKA 22	6.90	2.13	3.23	IR81023-B-116-1-2	6.07	2.63	2.31
DKA-M9	6.30	2.17	2.91	WAY RAREM	6.37	2.57	2.31
DKA 1	7.43	2.37	3.15	VANDANA	7.00	1.70	2.48
DKA 21	6.97	2.33	2.98	IR 77298-5-6-18	6.60	2.23	4.12
MILI 20-3-4-3-1	7.20	2.23	3.24	IR74371-70-1-1	6.37	2.33	2.95
				UPLRIL5	6.37	2.00	3.19

GL-Grain length, GW- Grain width and LBR- Length to breadth ratio