KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

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COMPARATIVE ASSESSMENT OF QUALITY OF LOCALLY PRODUCED COMMERCIAL AND IMPORTED RICE *(Oryza sativa)* VARIETIES IN GHANA

BY

GODFRED KOFI NYAMEKYE

JULY, 2016

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF PHILOSOPHY (M.Phil.) IN POST HARVEST TECHNOLOGY

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DECLARATION

I hereby declare that, except for specific references which have been duly acknowledged, this project is the result of my own research and it has not been submitted either in part or whole for any other degree elsewhere.

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DEDICATION

Dedicated to the most gracious and omnipotent God who made all things beautiful

and

To my loving wife; Grace and daughter; Aferba for their infinite love and encouragements.

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ABSTRACT

Rice consumption in Ghana is on the rise but the locally produced rice is perceived to be inferior or of less quality compared with imported rice. The need to make local rice more competitive and increase the awareness of its nutritive qualities to rice consumers in the country will boost food security in Ghana. This study was conducted to assess the qualities of some identified commercial locally produced and imported rice varieties in Ghana. Field surveys were conducted in the Northern, Ashanti and Greater Accra region to identify these rice varieties. Interviews and semi-structured questionnaires, were used in data collection from rice stakeholder (producers, processors, consumers, retailers and aggregators), randomly selected from each location. Twenty five (25) kg each of the 8 locally produced and imported rice varieties identified through the survey were obtained from farmers, cleaned, milled and bagged (local rice) and used for the study. Laboratory works to determine the proximate and functional properties of the samples were conducted at the Department of Horticulture of the Kwame Nkrumah University of Science and Technology, Kumasi and the samples stored in a certified Ghana Grains Council's warehouse in Tamale for a period of 4 months. Sensory attributes and the susceptibility of the rice sample to storage insect pests were also determined. The survey revealed that a lot of the imported rice varieties were preferred by respondents due to it aromatic flavour and clean quality. Royal feast and Texas rice were the most preferred imported brands. The 8 varietiesidentified were stored for a period of 4 months and at the end of each month (30days) samples were taken for analysis to determine their proximate, sensory and functional properties as well as insect infestations. The proximate study was done before the first month and after the fourth month of storage. The locally produced varieties were observed to have high protein (7.68% - 9.87%) and carbohydrate (79.77% - 85.38%) contents compared to the imported brands (81.03% - 82.72%). The crude fat (1.17% - 2.91%), crude fibre (1.27% - 2.82%) and ash (0.67% - 1.33%) contents were higher in the locally produced varieties than the imported brands/varieties. Storage periods and the type of varieties were observed to have significant effect (P<0.05) on the functional, functional and proximate properties of all the rice samples, Royal feast and Texas rice were the most preferred in terms of their loose grain particles or low sticky properties as compared with the local varieties which were observed to be high in starch hence found to be more suitable for most of the local Ghanaian dishes such as "Omotuo" (rice balls), waakye, porridge (rice water) and weaning meals for infants.

CHAPTER ONE

1.0 INTRODUCTION

Rice is currently the most important food security crop on earth. Right from the irrigated terraces of Asia and the large scale mechanized activities of the Americas to the rain fed operations of Africa; rice is the world's most valuable staple food. In Ghana, rice is now the second most essential staple food after maize, with an ever increasing growth in its consumption since the 1990s. Hardly does the locally produced rice meet the annual rice demand in Ghana. Imported rice contributes more than 50% of rice consumed in Ghana (Bam *et al.*, 1998) and has gradually been on the increase since the 1980s.

The main drivers of growth in per capita rice consumption, is due to urbanization and the insatiable satisfaction consumers, as urban populations consume considerably more rice than rural populations. From a steady level of 7kg -8kg per year during 1990, per capita rice consumption increased to 11.5kg/year on average through the 1990s and accelerated significantly to 27kg/year during the 2001-2005 period (MOFA, 2009). Future increases are projected by the Ministry of Food and Agriculture (MOFA) based on increasing urbanization, population growth and rising incomes. Based on these demographic trends and income growth, MOFA estimated that rice demand in the country will increase at an annual growth rate of 11.8% from 939,920 - 1,644,221 metric tons between 2010 and 2015 (MOFA, 2009).

Preferences for rice based on their sensory properties are attributed to consumers particularly from countries for which rice is their staple food. Quality requirement for rice differs per each rice consuming countries and within countries, however, a range of preferences can be found. Many of the well-known varieties for their quality were released several decades ago (Fitzgerald *et al.*, 2009). Over years, rice improvement programs have considerably increased achievable yield and yield potential, but these high yields have not been successfully combined with the high quality demanded by consumers.

All rice improvement programs in the past strived to replace low-yielding, high-quality varieties with higher-yielding versions of same. To date, rice breeders have generally failed in combining high yields with optimal quality since not all quality traits are defined (Fitzgerald *et al.,* 2009). Quality traits have been measured for decades with the use of quality evaluation programs and even the use of present-day tools for evaluating grain quality cannot differentiate an old variety from a potential replacement, while consumers are readily able to do so. The challenges faced by rice improvement programs is that consumers cannot elaborate on what is considered to be of good quality, hence it is difficult to identify new and relevant traits.

In Ghana, rain-fed rice contributes 84% of the total rice production in the country, producing average paddy yield between 1.0-2.4 Mt/ha. Irrigated area contributes a total of 16%, but produces average yields of 4.5 Mt/ha. Due to the lack of irrigation facilities and poor yields from the rain-fed areas, local rice production has not met domestic consumption demand. Also, the local rice supplies have not kept up with the changing consumer preferences for aromatic and long-grain white rice. As a result, rice importation from the U.S, Thailand, India, Vietnam, and Pakistan has increased significantly to satisfy Ghana's increasing demand and preferences for rice.

The need to intensify production and improve the quality of locally produced rice in Ghana to make it more competitive with the imported varieties cannot be overemphasized. Several factors such as poor physical and sensory properties have been identified to contribute to these variable qualities in rice. It is very common to find a lot of foreign material (organic and inorganic) such as stones and weed seeds in locally produced rice, and also other varieties having high levels of broken, chalky and damaged grains.

Reasonable pricing and grain quality are the two most important drivers for consumers' preferences of imported rice in the sub-region (Nwanze *et al.*, 2006). In Ghana, most studies in the rice sector have identified the poor quality of grain as a major problem (Al-Hassan *et al.*, 2008; Bam *et al.*, 1998; JICA, 2008; MOFA, 1999, 2000). The drift now in the West African sub-region is to put more importance on grain quality (Mohapatra, 2011). Grain quality is affected by the genotype, production practices and environment, harvesting, processing and milling systems (Mohapatra, 2011).

With Ghanaian consumer's preference still being skewed toward imported rice due to its taste, aroma and physical appearance, there is the need to evaluate the food qualities of our local rice varieties in order to sensitize all stakeholders in the rice value chain about the nutritional value and sensory properties as compared to the imported ones. In doing this, consumers for local rice may change hence increasing its demand and eventually encouraging local producers to expand and produce more quality rice to feed the nation. Equipped with the knowledge of the nutritional and sensory attributes of these commercially produced local rice varieties in Ghana, a local consumer can easily establish their specific food uses. For instance, preparation of some specific traditional Ghanaian dishes such as cooked/boiled rice with stew, grind and used as porridge, especially for weaning children or boiled, mashed and rolled into round balls eaten with soup (Omo Tuo)and also processed into flour and used in several pastry preparations. It is therefore imperative to establish the specific food uses of these rice varieties. This study will try to determine if there are significant differences in the functional, sensory and nutritional properties of imported and locally produced rice varieties and whether these properties are affected by their storability.

This work was carried out with the primary objective of identifying the various preferred locally produced commercial rice varieties in Ghana and evaluate their;

- proximate composition/nutritional properties
- sensory and functional properties
- storability or susceptibility to insect pest infestation

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 RICE

Rice (*Oryza sativa*) is an essential and easily accessible food for urban consumers in Ghana and most of sub-Saharan Africa (Tomlins *et al.*, 2007). Compared with all cereals in Ghana, the per capita consumption of rice is second to maize (Quaye *et al.*, 2000). Rice consumption in Ghana has tremendously increased over the last few years and this is primarily as a result of urbanization growth and the relative ease with which rice can be cooked. However, the increasing demand for rice in both quality and quantity far outweighs the local production. Over the past few years, production of rice in Ghana has stagnated around 170,000Mt of milled rice with a self-sufficiency ratio of 22% (MOFA, 2000). In addition to this, the quality of the rice produced is variable. To make up for the deficit, majority of the rice consumed in Ghana is imported. Data from the Ministry of Trade and Industry in 2005 showed that about 600,000 Mt of rice was imported into the country. This represented roughly a cash value of $200 million, contributing to 6% of Ghana's trade balance deficit.

The domestic production of rice in Ghana over the past years has been less than the national consumption needs. Demand for rice began to exceed supply due to population growth and improved standard of living. Undependable production and marketing systems have also contributed greatly to this situation. Consequently, government imports more rice in order to compensate for the short fall in the local supply.

It has been observed that, generally there is little incentive for farmers in Ghana to take steps in improving the quality and adding value to their produce, as there is no price differential for quality. Despite these perceived substandard quality, farmers producing rice locally, seemed to have little difficulty in selling their produce (Bam *et al.*, 1998).In a survey conducted for rice preferences, the percentage of respondents that said they regularly purchase or consume local rice in the three (3) major cities, Tamale, Kumasi and Accra were 74%, 38 and 40% respectively (Bam *et al.,* 1998). Nationally, there is a penchant for imported rice (although the local parboiled rice is most preferred in Northern Ghana). Locally produced raw milled rice generally does not appear to compete well with imported rice, yet it is still preferred by many consumers for the preparation of local dishes. Locally produced rice from irrigation schemes and processed using industrial mills are clean, white with low percentage of broken grain (< 10%) and can be compared with some varieties of imported rice brands. Some of these rice are graded, branded and marketed competitively in Accra alongside imported rice (Bam *et al.*, 1998).

2.1.1 Paddy Rice or Rough Rice

Worldwide, the term paddy rice, also known as rough rice is generally used to describe the rice as it comes from the field after harvest and threshed and each grain separated. The rice grain has a hard husk that protects the kernel inside. The husk or hull that covers the kernel is much thicker and tougher than most cereal grain husks. By weight, the composition of paddy rice is approximately: 22% husk (including about 2% trash), 10% bran, and 68% rice.

2.1.2 Brown Rice

Brown rice is the kernel/product we see after the husk is removed from rough rice. It is more nutritious than white rice, but very little rice is consumed in its brown form. Brown rice contains a bran layer that is about 12% of the brown kernel by weight. The protein content in the bran layer of brown rice is higher and has more lysine than in white rice even though white rice is much more nutritious than most cereal grains. The protein content in brown rice has one of the most complete essential amino acid profiles of any vegetable crop. The bran layer of this rice also contains digestible fibre as well as minerals and vitamins that are not found in milled and polished rice. Brown rice or even parboiled rice which contained more thiamine is very useful in minimizing the occurrences of beriberi than white milled rice. The oil content of rice bran contains several vitamin E components and valuable nutrients. Many states in America even passed laws some years ago that required white rice to be fortified with vitamins and minerals due to the loss of these nutrients when the rice bran is removed. Despite its nutritional value, consumption of brown rice is very low because of its long duration in cooking time, taste and texture. Unfortunately, once the rice husk is removed from kernel, the bran layer begins to go rancid and this contributes greatly to the bitter taste of brown rice.

2.1.3 Milled Rice

Milled Rice is one that has had its husk/hulls and bran removed. It is also referred to as white rice or polished rice. Most of the milled rice being sold in the local market has been milled very hard with some having their broken content removed. Less expensive milled rice imported into the Ghanaian markets may be milled to a lesser degree and may have higher percentages of broken grains. Most traditional consumers of rice always wash the rice before cooking to improve taste and texture. Almost all rice, either locally produced or imported is consumed in their milled form and not the paddy or rough states.

2.1.4 Broken Rice

Rice kernel or grain can become cracked in the field, during the drying process, threshing or the milling process. Cracks are usually caused by rapid movement of moisture within the kernel (drying too fast or moisture being added back to a dried kernel). These cracks often cause the rice kernels to break during milling thereby generating broken rice. The percentage of broken grains/kernels, relative to total the milled rice obtained during milling usually ranges from 12% to 50% in Ghana. Most rice are graded to separate or remove broken grain during the milling process to less than 5% in order to give the consumer a high quality rice.

2.1.5 Rice Bran

The proportion of rice bran in paddy rice ranges from 10% to 12%. There is no vivid distinction between the bran layer and endosperm. The more vigorous the rice is milled, the more the bran produced. Obviously some of the endosperm is also removed together with the bran during milling and so the properties that are unique to rice bran are diluted as the rice is milled vigorously. Rice Bran is a very nutritious and it contains a very higher protein content which has a better amino acid profile than the proteins found in white rice and most plant sources. Rice bran contains about 16% to 18% oil which is loaded with vitamin E components. Studies have shown that rice bran and rice bran oil lower cholesterol levels and improve cardiovascular health. Other high levels nutritional components of rice bran are vitamins (vitamin B), minerals, and essential fatty acids.

2.1.6 Parboiled Rice

Parboiled rice are paddy which has been through a short period of steaming or a special cooking process known as parboiling, prior to milling. The paddy rice is soaked overnight and then steam cooked, dried and milled. This process does not allow the kernel to swell during the steaming and its moisture level does not exceed 40% as compared to cooked table rice which is most often cooked to a moisture level of 64%. The starch granule is cooked (technically gelatinized), but not allowed to swell. The rice, while still in its paddy state, is dried and then passed through a standard milling process to remove the husk and bran.

This method of rice processing has been in existence for centuries in many countries and it's believed to have started in ancient India. Researchers in the early 1900's observed that parboiled rice retained some of the vitamins that existed in the bran but are lost in the milling process of the milled rice. This idea of parboiled rice was made famous by Uncle Ben in the United States with its converted parboiled rice. The process might have been initiated to sterilize the rice and allow for longer storage conditions since all paddy comes from the field with insect eggs in the germ and these eggs will hatch during favourable environmental conditions. The high temperature produced during parboiling process kills any insect eggs in the rice and eventually sterilize it. Parboiling also mends the cracks in the rice (glues broken rice back together) and dramatically improves the milling recovery of whole kernels in the rice. This improvement in milling recovery especially for poor quality paddy rice, can justify the cost of the process. Parboiling changes the rice texture and makes it firmer and less sticky. The kernel becomes much more durable and it takes longer time to cook as compared to white rice which is much easier to cook. It can be overcooked without becoming mushy or losing its grain shape.

2.2 RICE COMPOSITION

A rough rice or paddy (known as rice grain after threshing and winnowing) is the caryopsis or kernel of rice harvested with the hull or husk attached as shown in Fig. 2.1. The hull constitutes about 20% of the weight of the rice grain and it contains 25% cellulose, 30% lignin, 15% pentosan and 21% ash (Hoseney, 1994). Rice kernel, after the removal of the hull is referred to as brown rice which varies from 5mm to 8mm in length, and weighs about 25mg. Brown rice consists of approximately 2% pericarp, 5% seed coat and aleurone, 2 - 3% germ and 89 - 94% endosperm. Hemicellulose in rice endosperm is low and composed of arabinose, xylose, and galactose containing polymers, as well as protein and a large amount of uronic acids. During milling, bran is derived from the combination removal of the outermost layer of endosperm (aleurone), pericarp and seed coat and known as an excellent source of water soluble vitamins and vitamin E with little or no β-carotene or vitamins, C or D (Hoseney, 1994). Milling results in the loss of fibre, lipid, protein, reducing sugar and total sugars, ash and minor components like vitamins, free amino acids and free fatty acids from grains (Heinemann *et al.*,2005; Singh, 2001). The thin-walled endosperm cells are tightly packed with polygonal compound starch granules and protein bodies. The sub-aleurone layer is rich in lipids and protein and contains smaller amyloplasts and compound starch granules than the inner endosperm. Flour is made when the contents and cell walls of the endosperm cells are reduced to appropriate particle size.

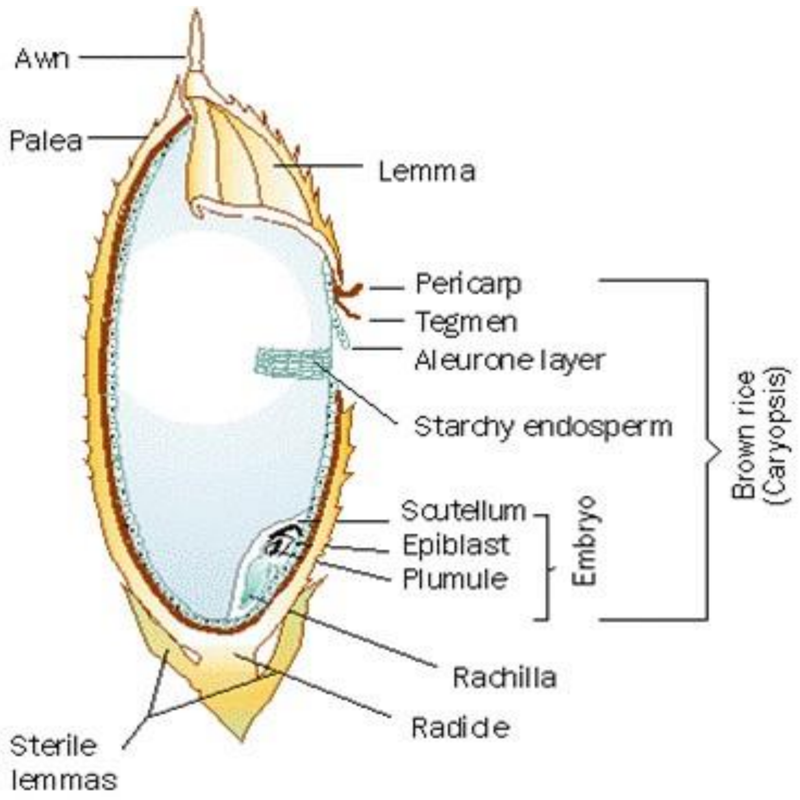


Figure 2.1: The structure of rice grain

Rice starch granules fill within the endosperm cells and fraction into linear chain amylose and branched amylopectin. Waxy rice contains 0 - 2% amylose content compared with more than 25% in non-waxy rice which in turn affects cooking properties, texture, water absorption ability, volume expansion, stickiness, hardness including the whiteness and glossiness of cooked milled rice (Juliano 1985). Suggested classification based on amylose content is waxy (0-5%), very low (5-12%), low (12-20%), intermediate (20-25%), and high (25-33%) (Juliano 1985). The amylose content in japonica, indica, and javanica rice is in the range of 0-20%, 25-33% and 025% respectively. Monoacyl lipids and different volatile flavour compounds such as alcohols, lactones, aldehydes and terpenes are capable of inducing the helication of amylose and act as inclusion partners (Heinemann *et al.,* 2005).

Rice contains about 3% lipids which is concentrated in the peripheral portions of the grain. Rice lipids can be classified as glycolipids, neutral lipids and phospholipids with no difference in terms of the ratio between indica and japonica (Mano *et al.,* 1999). The lipid content of brown and milled rice range from 2.1% -3.2% and 0.61% -0.95%, respectively (Singh, 2001). Juliano (1985) classified rice lipids into starch lipids which are linked with starch granules and nonstarch lipids which are distributed throughout the grain. Starch lipids are mainly fatty acids (palmitic and linoleic acids) and phospholipids attributed to the formation of the helical inclusion complex (Choudhury and Juliano 1980; Kitahara *et al.*, 1997). Rice oil contains a phenolic antioxidant (oryzanol), an ester of ferulic acid, and triterpene alcohols (Juliano 1985).

The protein content of rice is generally lower than that of the other cereals. For brown rice, the protein content ranged from 6.6% - 7.3% while milled rice ranged from 6.2% - 6.9% (Singh, 2001). The first limiting amino acid based on human requirement is Lysine, followed by threonine (Juliano 1985). Rice protein fractions such as albumin, prolamin, globulin and glutelin are soluble in water, alcohol, salt and alkali respectively and varied among rice. The distribution of different solubility fractions is uneven. Albumin and globulins are concentrated in the embryo and aleurone layer. The storage proteins (oryzenin and prolamin) occur in the highest amount in the endosperm. Glutelin (oryzenin) was the highest range (64% -75 %) of the total protein (Basak *et al.,* 2002). Degree of polishing which removes the peripheral layer of the kernel was inversely correlated with the protein and fat content (Pal *et al.*, 1999).

2.3 Type of Rice

There are over 120,000 different rice varieties worldwide and only a very small number offer the quality that meets the standard for commercial production in Ghana. These varieties can be classified into long, medium and short grain rice. The primary variations in these varieties are their cooking characteristics, texture and some subtle flavour variation. They can be used interchangeably, depending on the recipe.

Long grain rice has a much slender kernel and 3 to 4 times longer than its width. They are light and fluffy with more separate grains when cooked due to their starch composition while Short grain rice are almost round in shape with short and plump kernel. When cooked, the grains become soft and cling together, yet remain separate and slightly chewy and the Medium grain rice has a wider but shorter kernel compared to the long grain. They are more moist and tender than the long grains when cooked and have a greater tendency to cling together.

2.4 RICE PRODUCTION

Rice (*Oryza sativa*) is indigenous to Asia and provides a staple food for almost 50% of the world population. The other cultivar, *Oryza glaberrima*, is only cultivated in Africa with on a small scale (Juliano, 1985a). Two major eco-geographical races of *Oryza sativa* are japonica rice and indica rice. These rice races are grown is in the temperate region and in the tropical and subtropical areas, respectively. Javanica rice belongs to the japonica race of *O. sativa* and is cultivated in Indonesia. In 2006, the world produced about 638 million tonnes of paddy rice which was equivalent to 429 million tonnes of milled rice (FAO, 2007). Production is geographically intense in Eastern and Western Asia with over 90% of the world output. China and India account for more than half of world production but mostly for domestic consumption. Thailand, Vietnam and Pakistan are the top three of the world's largest milled rice exporting countries while the non-Asian producer like the United States ranks the fourth, exporting about 3.3 million tonnes of milled rice to the world's market (FAO, 2007).

Rice, which is mostly consumed in its cooked milled form, is also processed into flour or starch for use in the pharmaceutical industry and animal feed products. Due to its outstanding characteristics, there are many applications or uses for rice starch. It has a neutral taste and hence does not affect the final flavour of the product it was used for as ingredient (Bao and Bergman, 2004). Rice starch has the smallest granules of the commercial starches (2-9m) (BeMiller, 2007) and they are known to form soft gels, turning them into an appealing fat mimetic in a wide range of food products. Also, rice starch does not induce allergic responses in human because they do not contain gluten (Bao and Bergman, 2004).

The global rice trade is segmented into long-grain, medium and short grain, aromatic and specialty (primarily glutinous) rice which approximately accounts for 75%, 12%, 12% and 1%, respectively (FAO, 2007). 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 near future, rice quality will become more imperative in procurement decisions as all consumers, who depend solely on rice as their daily meal, will demand for higher quality rice (Traore, 2005). However the definition for quality is very difficult since it is defined by the consumer and their preferences are highly variable. For instance, consumers in the Middle East prefer well milled aromatic long grain rice while those in the European regions generally prefer nonaromatic long grain rice because the presence of any scent is a sign spoilage and contamination (Troare, 2005). In Ghana, long grain and aromatic rice are usually boiled and served with vegetable sauces or in preparing Jollof or fried rice. The demand for aromatic long grain rice varieties in the Ghanaian markets is very high; hence they are the most expensive. Short grain rice is used to prepare “Omo tuo”; this is tenderly cooked rice that is moulded into balls and taken with palm nut soup or ground nut soup.

The estimated range of rice production in Ghana is between 200,000 to 300,000 Mt of paddy or approximately 120,000 to 180,000 Mt of milled rice and the bulk of these are produced in the Northern, Upper East, and Volta Regions. Rainfall remains the major driver of production variance. Rice production in Ghana can be categorized into three main cropping systems (see Table 2.1). Lowland rain-fed, which accounts for 78% of the production is the type by which rice are planted in the receding waters of the Volta river and other river bodies; Upland rainfed accounts for 6% and the Irrigated system of rice production accounts for 16%.

Table 2.1**:** Categorization of paddy fields in Ghana

	Lowland rain-fed	**Upland rain-fed**	**Irrigated**	**Total**
Planted Area (Ha)	93,750	18,750	10,200	122,700
Paddy (MT/Ha)	2.4	1	4.5	2.4
Paddy Production (MT)	224,700	18,750	45,900	289,350
% of Total Area	76	15	8	100
% of Total Production	78	6	16	100

Source: "The study on the Promotion of Domestic Rice in the Republic of Ghana," MoFA and JICA, (Final Report, March 2008).

By the end of 2008, the estimated value of paddy production in Ghana was 301,921Mt, with recovery of approximately 181,000Mt of milled rice, produced on 132,921 hectares of land. The average yield for upland production was 2.27Mt/ha of paddy and lowland rice aggregated. It is generally agreed that current localized production accounts for between 30 to 40% of domestic consumption (approximately 600,000 Mt of milled rice).

Currently rice yields vary significantly by production systems but average yields ranged from 2.5 to 4.2 Mt/ha in the major rainy season and 2.1 to 3.5 Mt/ha during the minor rainy season. This is compared to 9.8 Mt/ha for Egypt, 7 Mt/ha for the United State and Japan, and 4 Mt/ha recorded for Vietnam. Vietnam is a high-volume rather than a highly efficient producer while Ghana's highest producer yields hardly exceed Vietnam's national production average. Alternatively, Ghanaian yields are relatively high given the lack of access to improved seed, agro-inputs and appropriate mechanization services. It can be assumed that, with access to all these agricultural resources, Ghana must be able to produce rice at reasonably high levels of efficiency and quality.

Ghana's potential for irrigated perimeters is 1.9 million hectares, roughly 0.46 percent of which is currently developed. Since the 1960s, 22 public irrigation schemes totalling 8,700 hectares have been established and are currently used for the production of rice, maize and vegetables.

Mechanization levels in rice production are low throughout Ghana, although most farmers hire tractor services for ploughing and harrowing. In the Northern Regions, bullock-drawn ploughs are also common. All other production and post-harvest activities are done manually, especially by smallholders. Other constraints to production include low land-levelling of paddy fields and lack of bunds to retain rain water; inadequate supply of certified seed, fertilizers and other agrochemicals; and inadequate credit facilities to ensure investment in productivity-enhancing technologies.

Table 2.2: Year2012 and 2013 National Rice production

COMPARISON OF 2012 AND 2013 RICE PRODUCTION IN GHANA						
REGION	**CROPPED AREA**		**AVERAGE YIELD**		**PRODUCTION ESTIMATES**	
	YR 2012	**YR 2013**	**YR 2012**	**YR 2013**	**YR 2012**	**YR 2013**
WESTERN	19,809	22,500	1.29	1.27	25,464	28,604
CENTRAL	1,731	1,630	1.86	1.62	3,221	2,648
GREATER ACCRA	2,917	3,057	6.45	6.48	18,822	19,808
VOLTA	25,305	40,200	3.26	3.99	82,546	160,467
EASTERN	7,306	8,900	3.36	3.36	24,567	29,939
ASHANTI	10,268	13,300	2.70	2.89	27,748	38,399
BRONG AHAFO	3,902	4,128	1.61	1.63	6,268	6,713
NORTHERN	69,253	75,000	2.39	2.16	165,328	162,297
UPPER EAST	44,059	42,088	2.73	2.70	120,171	113,523
UPPER WEST	4,978	5,102	1.41	1.40	7,000	7,127
TOTAL	**189,529**	**215,905**	**2.54**	**2.64**	**481,134**	**569,524**

Source: Statistics, Research and Info. Directorate (SRID), Min. of Food & Agric. - May, 2014

2.5 RICE USES

There is a wide range in the use of rice worldwide (Shilpa, A., 1996); primarily among them is the use as a main meal/dish (source of nutrient) for both humans and farm animals. Countries also generates income from rice production through foreign exchange, some also use it for medicine. Some commercial or industrial uses of rice products include rice flour, starch, rice flakes, rice cakes, rice milk and other extended uses such as rice husk for fuel, rice bran for animals' feed, broken rice used as snacks and beverages**.**

2.6 CONSUMPTION PATTERNS

Consumption patterns can be best understood in terms of three factors; i) demand shifts to rice from tubers as incomes rise, ii) rural versus urban patterns, and iii) varietal preference patterns. In Ghana, as is the case throughout the region, household consumption patterns shift to rice from other coarse grains and tubers as incomes rise. Demand for rice will therefore continue to outpace population growth as incomes rise.

Ghana differs from many other countries in the region in having large and diverse sources of dietary carbohydrates, whereas for coastal countries like Liberia and Sierra Leone, rice is the principal carbohydrate source. In Ghana, maize, millet, sorghum, cassava, yam, cocoyam and plantain are widely consumed starch staples and these are relatively cheaper than rice.   The current consumption of rice in Ghana is estimated around 30kg/capita per year (Table 2.3) with a projected demand in 2015 of as much as 63kg/capita per year driven by stable improvements in income and a population growth of 27.5%. With a consistent income patterns and the diverse sources of carbohydrate diets in Ghana, rice consumption in rural communities (where poverty levels are higher) is much lower than in the urban cities. Rice comprises only about 10% of the total national carbohydrate consumption and rural consumers, especially those producing alternative cereal and tuber crops are less vulnerable to rice price fluctuation than the urban consumers. By contrast, the urban consumers have a strong penchant for the aromatic long grain rice, which is mainly imported from Vietnam or Thailand and for which there are few locally produced substitutes.

Table 2.3: Estimation of per capita Rice consumption in Rural and Urban areas of Ghana

		Urban	**Rural**	**Whole country**
Yearly Consumption	Population	9,170,000	11,360,000	20,530,000
	Per Capita (Kg)	38.0	9.20	22.10
	Total (MT)	348,500	104,800	433,300
	Consumption Ratio (%)	76.90	23.10	100

Source: Estimation based on interviews by JICA Study Team, 2006

2.7 PHYSICOCHEMICAL PROPERTIES RELATED TO PROCESSING AND EATING QUALITY

Processed milled rice contains about 90% starch and its amylose content has a greater influence on the processing properties and eating quality. There is a direct correlation between amylose and the hardness, whiteness and dullness of cooked rice and water absorption during cooking. Rice varieties which are low in amylose level are soft and sticky in texture when cooked while those with high amylose content are hard and flaky in texture (Juliano, 1985). Rice varieties are usually categorized in terms of their amylose content as waxy (1-2% amylose), very low (29%), low (10-20%), intermediate (20-25%), and high (25-30%) (IRRI, 2007b). Waxy rice is found in the indica and japonica rice sub-species (Bao and Bergman, 2004).

As the amylose content in rice is a very essential physicochemical property in terms of its cooking and eating quality, consumer preferences are also influenced by the gelatinization temperature (GT) of a rice variety since GT is directly linked with cooking time (Juliano, 1993). The heat energy required to totally gelatinize starch is very essential for food processors, because it determines the cooking time, heat input and temperature of processing (Bao *et al.*, 2007).

2.8 FUNCTIONAL PROPERTIES

Functional properties are the fundamental physicochemical characteristics that reveal the complex interaction between the composition, molecular conformation, structure, and the physicochemical properties of food components and their associated environment (Kinsella, 1976; Kaur and Singh, 2006; Siddiq *et al.*, 2009). Functional properties are necessary in the evaluation and possible prediction of how new fat, fibre, proteins and carbohydrates may behave in specific systems as well as to demonstrate whether the said protein can be used to stimulate or replace conventional protein (Mattil, 1971; Kaur and Singh, 2006; Siddiq *et al.*, 2009). The property of food is characterized by the structure, quality, nutritional value and the acceptability of the food product. The functional property of a food substance is determined by physical, chemical, and organoleptic properties of the food. Example of functional properties includes water absorption capacity, oil absorption capacity, bulk density, frothing ability, elasticity, gelation, emulsification, hydration (water binding), viscosity, foaming, cohesion, adhesion and solubility. One of the objectives of this work involves the collection of data on functional properties of rice flour. This will provide useful information to industries and other alike on the subsequent acceptance of the different local rice varieties produced in Ghana.

2.9 SENSORY EVALUATION

Sensory evaluation is defined by the Institute of Food Technologists as "a scientific discipline used to evoke, measure, analyse, and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of smell, taste, sight, touch and hearing" (Dethmers *et al.* 1981). Scientific ideologies that are taken from food science, physiology, psychology and statistics are considered to elicit objective responses to the properties of foods (Piggott *et al.* 1998). Sensory assessment is more concerned with accuracy, precision, sensitivity and the avoidance of fake results (Lawless and Heymann 1999). Two major classifications of sensory tests are developed according to their prime purpose and most effective use: analytical tests and affective tests. The analytical tests are classified as discriminative tests and descriptive tests. The use of these tests is to show the differences/similarities and to identify and quantify the sensory properties respectively. The affective tests assess the preference and acceptance of a product. There are a number of variations of discrimination tests including the Pairedcomparison, Duo-Trio, Triangle, Ranking and Rating difference (Dethmers *et al.*, 1981), A-not A, 3AlternativeForced Choice (directional difference), and Two-out-of-Five test (Meilgaard *et al.*, 2007). Different tests are designed to measure difference, not the sameness. If the frequency of correct solutions is higher than that expected by chance, then a difference is declared.

2.9.1 Descriptive sensory analysis

Descriptive sensory analysis is an impartial tool used to describe and analytically measure traits of flavour, aroma, and texture of foods by a trained panel (Meilgaard *et al.* 2007). This method has been used widely for determining the effect of different growing and processing conditions on sensory properties of rice (Champagne *et al.* 2004a, b, Meullenet *et al.* 1999).

Descriptive sensory tests are among the most complexed tools that use trained panellists to characterize the qualitative components and intensify the quantitative components (Lawless and Heymann 1999; Meilgaard *et al.*, 2007). Qualitative components are the perceived sensory attributes such as aroma, flavour, appearance, texture of the products. Quantitative components are expressed by the assigned values using a proper scale including category scales, line scales, and magnitude estimation (ME) (Meilgaard *et al*., 2007). Improper use of scaling technique affects the validity and reliability of terms (Meilgaard *et al.*, 2007). All descriptive analysis methods require the training for the selected panel. Generally during the training period, the panel will develop the sensory language to be used to describe the product with the aid of reference standards to align the concept of each panellist into a same way (Munozand Civille 1998). With exception to FCP method, terminology generation is done after the completion of training. Numerous articles discuss the selection of sensory panellists including screening tests (Issanchou *et al*., 1995; McDaniel *et al*., 1990) and monitoring panel performances (Derndorfer *et al*., 2005). A broad array of factors is suggested to select panellists for descriptive analysis including health status, allergies, verbal creativity, availability, concentration, motivation, team player, smoker, dietary habits, education, sensitivity, previous experience, dentures, medication, use of products, supplements (Piggott *et al.*, 1998). Details for the numbers of hours required and training procedure are well elaborated elsewhere (Lawless and Heymann 1999; Stone and Sidel 2004; Meilgaard *et al*., 2007).

There are a number of different techniques of descriptive analysis including the Flavour Profile Method (FPM), Texture Profile Method (TPM), Quantitative Descriptive Analysis (QDA), the Spectrum™ method. The first two techniques have a commonality in that the consensus for all attributes is achieved from a highly trained panel. However, TPM is designed to better interpret the relationship between rheology and its nomenclature rather than to describe texture properties, unlike the FPM that is used to assess the flavour and aroma impressions of food. The latter two methods differ distinctly from FPM and TFM in that they are designed to take measurements from individual panellists and then generate a panel average, rather than generation of a group consensus profile as with FPM and TFM (Piggott *et al.*, 1998). Also, panellists are given more standards and training to reduce panellist variability and so increase discriminability between products and over time. Subsequent data analysis is introduced to remove unwanted variation. A detailed overview of all the four methods can be found in the Manual on Descriptive Analysis Testing for Sensory Evaluation (Hootman 1992). The Quantitative Flavour Profiling (QFP) is a modified method from QDA developed by GivaudanRoure, Switzerlend (Stampanoni 1993). This method focuses on flavour only using language generated by flavorists who do not involved in the evaluation. Free-Choice Profiling is a variation of descriptive analysis which is different from QDA and the Spectrum method where consumers are allowed to use any number of their own attributes to describe and quantify product properties. Data from this method is analysed by generalized procrusted analysis. Timeintensity scaling (TI) is a special case of descriptive analysis, where a single characteristic is tracked as it changes over a period of time (Murray *et al*., 2001).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 FIELD SURVEY

The survey was conducted from September to November, 2014 to sample views of stakeholders in the rice value chain in some parts of Northern and Southern Ghana. Information gathered from respondents (rice traders, processors, Aggregators, farmers, researchers and consumers) were used in the identification of the most preferred locally produced commercial rice varieties in the country. On the basis of this, six preferred locally produced rice varieties and two foreign varieties were identified and selected for the work. 84kg each of the six selected local varieties were acquired from selected farmers within the Kumbungu District in Northern region at moisture contents ranging from 12%-16% at harvesting. These were properly cleaned and destoned before milling and all foreign materials and stones were again hand-picked from the milled rice before bagging and storage.

3.1.1 Questionnaire Design

A semi-structured questionnaire was used to access the required data needed. Information solicited in the questionnaire included local rice varieties, preference for local or foreign brands (varieties), storage insect infestation, and postharvest practices such as threshing carried out on the farms and markets varietal preferences.

3.1.2 Sampling Area

Sampling was done in some selected districts in the three major regions where studies have shown have the highest rice producing and consuming areas in Ghana; Northern, Ashanti and Greater Accra Region. These regions have high rice production, processing and consumption respectively in the country.

3.1.3 Questionnaire Administration

Semi-structured questionnaires were administered to traders, aggregators, processors, farmers and consumers in the rice value chain. Trader selection was based on those who sold local and foreign rice brands. The farmer selection was based on those who cultivated only rice so as the aggregators and processors. A total of one hundred (100) semi-structured questionnaires were administered to respondent in the Northern region and fifty (50) each to actors in the Ashanti and Greater Accra Regions.

3.1.4 Statistical Analysis

Data collections from all sampling locations were analysed statistically using the Statistical Package for the Social Scientist (SPSS) version 16. Descriptive statistics were statistical tools employed in the analysis. The data output were presented in tables and graphs (pie charts and bar graphs) with values presented in percentages.

3.2 LABORATORY EXPERIMENTS

3.2.1 Location of Experiment

The laboratory experiments were carried out in the Horticultural Department of the Faculty of Agriculture, College of Renewable and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi between January to June, 2015.

3.3 FLOUR PREPARATION METHOD

3.3.1 Preparation of rice flour

The rice flour for the functional and proximate analysis was produced using the eight identified varieties. 1.5g of each of the eight milled and well-cleaned rice varieties were ground using an electronic grain cracker blender. The resultant fine flour obtained from the rice kennels were stored in labelled air-tight containers and sent to the laboratory for analysis. If the flour is not stored in an air-tight container, it might become mouldy.

3.4 PROXIMATE COMPOSITION STUDIED

The usefulness of cereals grains, which to a great extent is dependent on starch and protein content of the grain flours, contribute immensely to the formulation and properties of the end product. Therefore, the flours from the rice samples were analysed for their proximate compositions and functional properties. Each flour sample was analysed for moisture, crude protein, crude fat, ash, crude fibre and carbohydrate

3.4.1 Moisture Content

The moisture content of the samples were determined using the AOAC (2005) procedure. By weighing 2g of the sample into an aluminium moisture can, the moisture content of each of the sample was then determined. The sample was dried to constant weight at 105±2C.

$$\text{Moisture content} = \frac{(\text{Weight of can + sample}) - (\text{Weight of empty can})}{(\text{Weight of sample})} \times 100$$

3.4.2 Crude Protein

The Protein levels of the samples were determined using the Kjeldahl method with a Foss Tescator protein digester and a KJECTEC 2200 distillation device according to the AOAC (2005) procedures. Concentrated H_2SO_4 (15ml) and 2 tablets of catalyst were put into a Kjeldahl digestion flask which contained 2g of the sample. This flask was put in the digester in a fume cupboard and switched on. The digestion was done for 45 minutes to obtain a clear colourless solution. The digest was then distilled with 4% boric acid and 40% Sodium hydroxide solutions was added to it in the KJECTEC 2200 distillation equipment until distillation was completed.

The distillate was then titrated with 0.1M HCL until a pink colouration was reached indicating the end point. A blank was run under the same condition as with the sample.

$$\text{Crude Protein} = \frac{[\text{Titre value (of sample)} - \text{blank}] \times 0.01 \times 14.01 \times 6.25 \times 100}{\text{Weight of sample} \times 1000}$$

3.4.3 Crude Fat Content

Crude fat of the samples were extracted in a Soxhlet extractor with hexane and measured gravimetrically. 1g of the sample was weighed into an extraction thimble and stopped with greaseless cotton. The round bottom flask was dried clean, cooled and weighed before commencing the extraction. The thimble was placed in an extraction chamber and 80ml hexane was added to extract the fat. The extraction was carried out at 130^{0}C, lasted for 2hour after which the fat collected in the bottom cans were cooled in a desiccator.

$$\text{Crude Fat} = \frac{\text{Weight of fat} \times 100}{\text{Weight of sample}}$$

3.4.4 Crude Fibre

A sample weight of 2g was put into a 0.5litre conical flask and100ml of sulphuric acid (12.5M) was heated to boiling and poured into the conical flask containing the sample. The contents were again boiled for 30 minutes ensuring that the level of the acid was maintained by the addition of distilled water. After the 30 minutes, the contents were then filtered through a muslin cloth held in a funnel. The residue was rinsed thoroughly until was no longer acidic to litmus. The residue was then emptied into a conical flask. 100ml of sodium hydroxide (12.5M) was then brought to boil and then poured on the sample in the conical flask. The contents were then boiled for another 30 minutes making sure acid level was maintained by the addition of distilled water. After the 30 minutes, the flask contents were then filtered through a muslin cloth held in a funnel. The residue was rinsed thoroughly until the water was not alkali to litmus. The residue was then emptied into a dried crucible and ashed at 550℃.

$$\text{Crude Fibre} = \frac{\text{Final weight of crucible} - \text{Initial weight of crucible} \times 100}{\text{Weight of sample}}$$

3.4.5 Ash Content

A sample weight of 2g was poured into a well incinerated crucible and then burnt to ash in a muffle furnace at 600^0C for a period of 2 hours. The ash content was calculated as:

$$\text{Ash Content} = \frac{\text{Weight of Ash} \times 100}{\text{Weight of sample}}$$

3.4.6 Carbohydrate (Nitrogen-Free Extract)

The calculation of carbohydrate was made after completing the analysis for moisture content, crude fat, crude protein, crude fibre and ash contents. The calculation was done by adding the values of percentages on dry basis of these analysed contents and subtracting from 100%.

% Carbohydrate = 100% - [%moisture + %ash+ %crude protein + %crude fat + %crude fibre]

3.5 FUNCTIONAL PROPERTIES STUDIED

Functional properties of the identified rice varieties studied were bulk density, water and oil absorption capacity, swelling capacity and foaming capacity.

3.5.1 Bulk density

A sample flour weight of 50g was put into 100ml measuring cylinder and tapped to a constant volume using the Okaka and Potter (1979) procedure and the bulk density (g/ml) calculated using the formula:

$$\text{Bulk density} = \frac{\text{Weight of flour (g)}}{\text{Flour volume (ml)}}$$

3.5.2 Water and oil absorption capacities

1g of rice flour was mixed with 10ml distilled water or refined cooking oil in a pre-weighed 20ml centrifuge tube. The slurry was agitated for 2mins, allowed to settle for 30mins at 28°C and then centrifuged at 500rpm for 20min. The clear supernatant was decanted and discarded. The adhering drops of water or oil in the centrifuge tube were removed with cotton wool and the tube was weighed, the weight of water or oil absorbed by the 1g of flour or protein was calculated and expressed as water or oil absorption capacity (Beuchat, 1977).

3.5.3 Foaming capacity

1g of rice flour was whipped with 100ml distilled water for 5min in a Binatone blender at 500rpm and poured into a 250ml graduated cylinder. The volume of foam at 30sec after whipping was expressed as the foam capacity.

3.5.4 Swelling capacity

Swelling capacity was determined as described by Leach *et al.,* (1959). 1g of rice flour was added to 10ml of distilled water in a centrifuge tube and heated in a hot water bath at a temperature of 80°C for 30mins while shaking the tube continuously. After the heating, the suspension was centrifuged at 1000g for 15mins. The supernatant was decanted and the weight of the paste taken.

The swelling capacity was computed as:

Swelling capacity= <u>Weight of the paste</u>

Weight of dry flour.

3.6 SENSORY PROPERTIES STUDIED

Sensory evaluations were carried out on cooked rice samples from the identified varieties and the assessment were done by a 15 semi-trained member panel using a 5-point hedonic scale with a scoring of 5 as the highest (like a lot) and 1 as the least (Dislike a lot). These were done for all samples at the end of each storage month for a period of four months.

Approximately300g of each of the eight identified rice varieties were cooked in 650ml of saline water. The cooked samples coded randomly with numbers from 1 to 8 and served in random order to the sensory evaluation panellist at ambient temperature. Sensory parameters evaluated were, Aroma, Colour, Flavour, Taste, Texture, Stickiness, Hardness and Loose grain particles (non-stick grains). Before and after every tasting of a sample, the panellists were made to rinse their mouth with mineral water.

3.7 STORABILITY AND INSECT INFESTATION

Twenty five kilogram (25kg) of each of the eight (8) identified locally produced and imported rice varieties(milled) were stored in a Ghana Grains Council (GGC) certified warehouse in Tamale for a period of four months. Samples from each replication were taken for visual inspection of insect infestation at the end of each month (30 days). These were done before preparing flour samples for the Proximate & Functional analysis and the determination of Sensory properties. The number of insects found in every 2g sample were counted and recorded per each storage month.

3.8 EXPERIMENTAL DESIGN

A Complete Randomize Design (CRD) was the experimental design used. Experiments were replicated three times. The flour prepared served as the experimental treatments.

3.9 STATITICAL ANALYSIS

All the data collected were analysed statistically using Analysis of Variance (ANOVA) and the statistical package used was STATISTIX software. Testing for differences between means was at 1% P level (P = 0.01).

CHAPTER FOUR

4.0 RESULTS

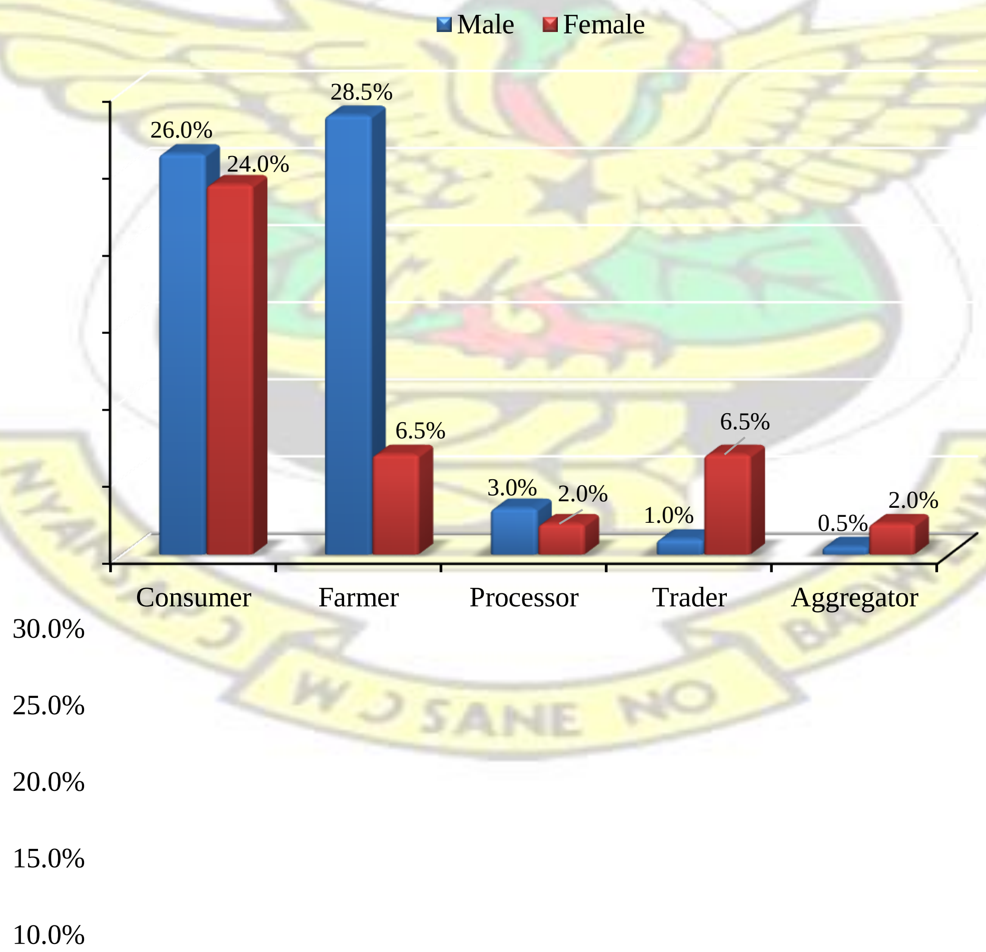
4.1 INTRODUCTION

This chapter presents the findings of the study. It reports on the biodata and responses of respondents during the field survey, comprising of rice consumers, producers, processors, aggregators and traders. It also contains results of the proximate, functional and sensory properties studied and the susceptibility of the rice samples to insect pest over a storage period.

4.2 FIELD SURVEY

4.2.1 Respondents background information

The survey data indicated that out of the 200 respondents interviewed within the three selected regions in Ghana, 118 (59%) of them were males while 82 (41%) were females. Majority (50%) of the respondents interviewed were rice consumers, 35% as farmers (rice producers), 7.5% as traders, 5% as processors and 2.5% as aggregators (figure 4.2)



5.0%

0.0%

Figure 4.1: Gender of respondents by categories

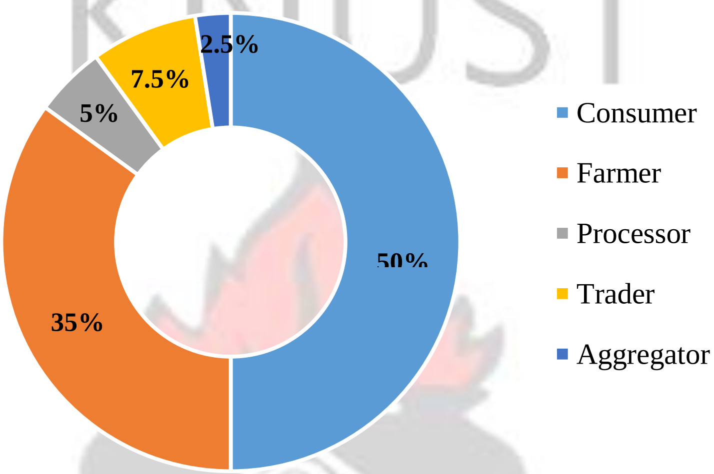


Figure 4.2: Categories of survey respondents

On the level of education of all respondents, 31% had no formal education; a total of 40% (25% for MSCL/JSS, 15% for Primary) had basic education while 12% and 17% were educated up to Secondary/Technical and Tertiary levels respectively. The farmers category of respondents recorded the highest in informal education (57.1%) whiles that of the consumers recorded the highest in formal education up to the basic level (44.9%). None of the respondents in the trading, aggregation and processing categories had tertiary education.

Tertiary

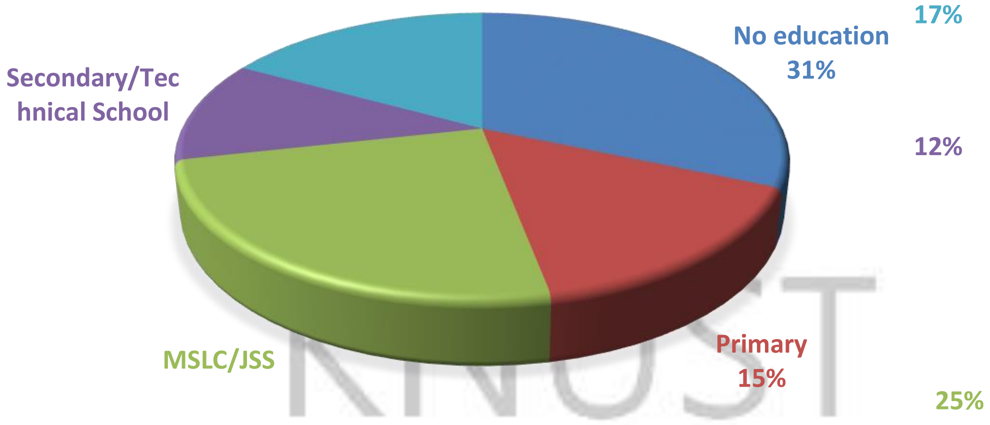


Figure 4.3: Educational level of respondents

4.2.2 Rice consumption and consumer preference

From Figure 4.4 and 4.5, 99.5% of the respondent consumed rice out of which 89.9% consumed locally produced rice and 10.1% do not consume locally produced rice at all. However, 68.5% preferred the local rice whiles 31.5% preferred the imported rice from other countries. Various locally produced rice varieties were identified through the interviews of farmers, processors, traders and consumers. Most (61.4%) of respondent consumed Gbewaa rice variety, 14.2% consume Togo mashal, 8% consume Mandi, 6.8% Red rice, 6.3% Sikamo and 3.4% AGRA rice (new variety).

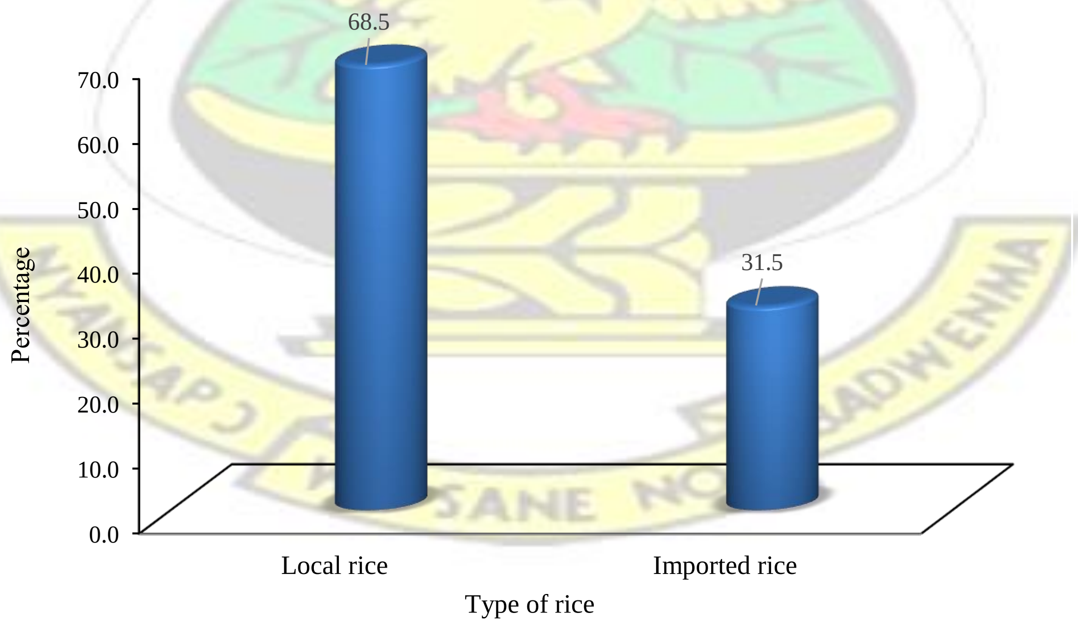


Figure 4.4: Preference of milled rice in the Ghanaian market

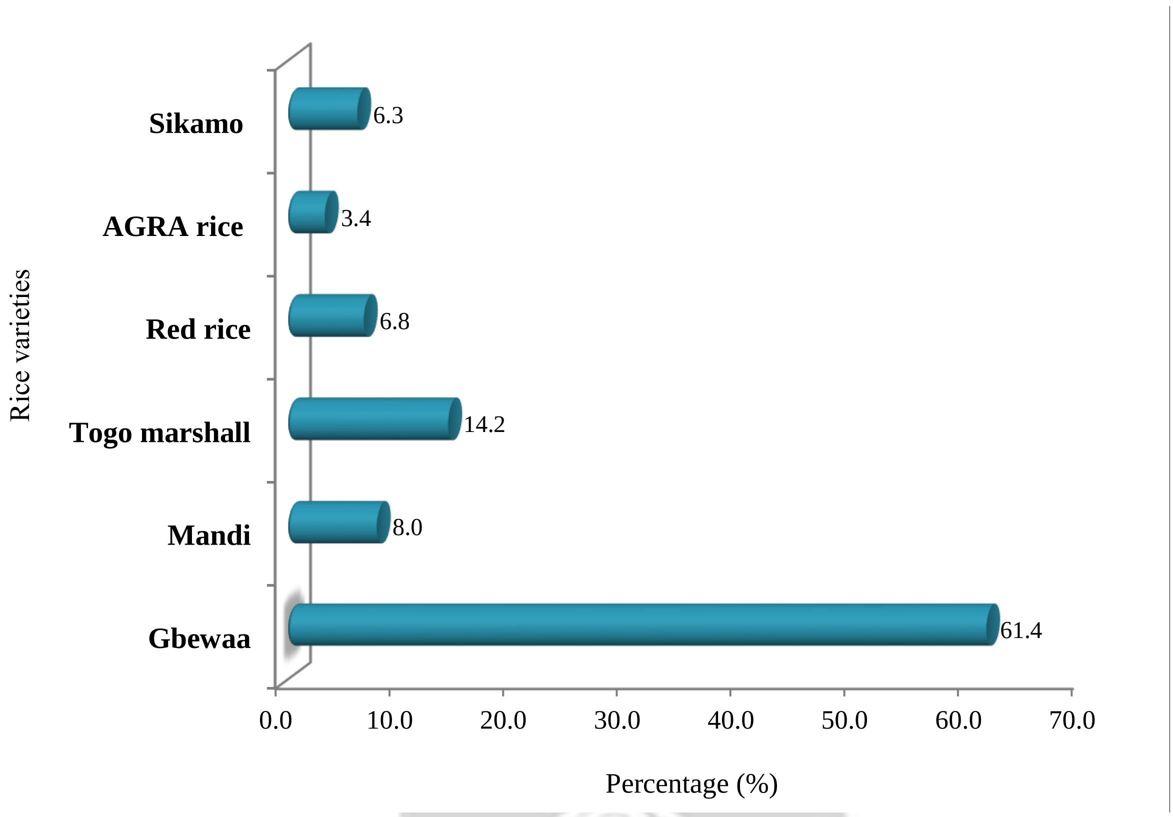


Figure 4.5: Identified locally produced rice varieties

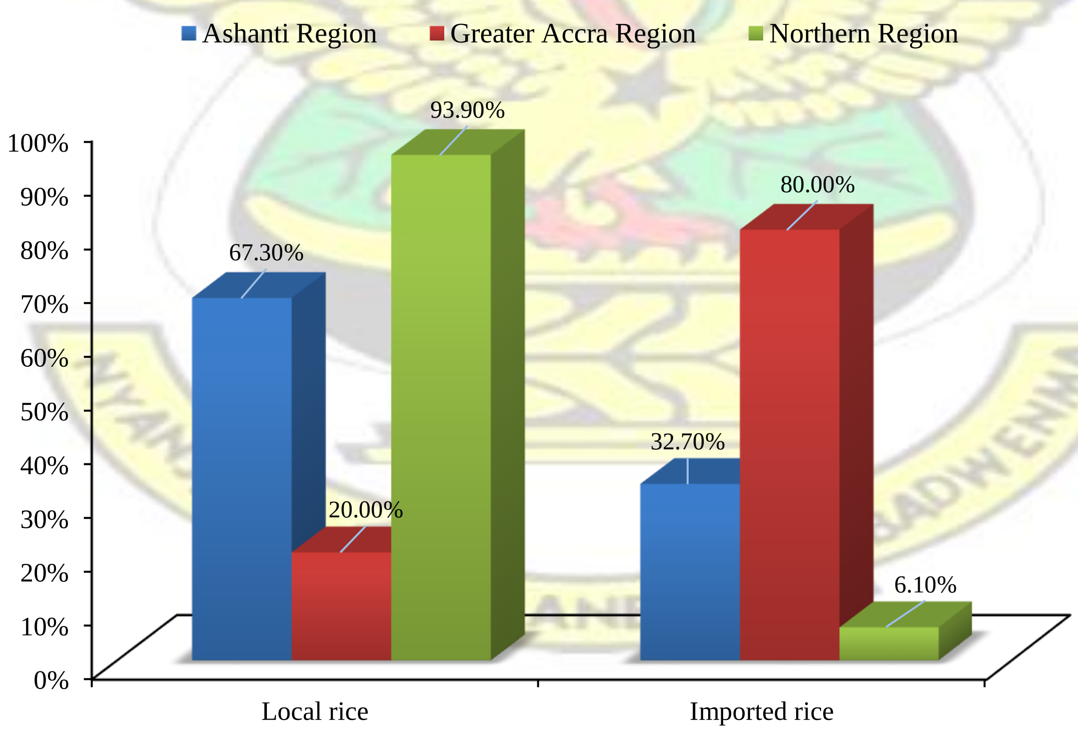


Figure 4.6: Rice preference per region

Figure 4.6 presents the type/source of rice preferred by respondents by region. Out of the 49 respondents from Ashanti Region, 33 (67.3%) preferred local rice whilst the remaining 16 (32.7%) preferred imported rice. Similar trend was observed for the northern region where majority of the respondents' preferred local rice (93.9%) than imported rice (6.1%). However, for Greater Accra Region, respondents preferred imported rice (80%) to local rice (20%). The above results is confirmed by the chi-square value of 83.827 (df=2, p=0.000) which meant that type of rice preferred is dependent on respondents' region.

4.2.3 Reasons for consumer preference of rice type

The survey respondents gave various reasons for their choices of rice for consumptions and this was greatly influenced by their geographical locations (Bam *et al.*, 1998) as seen in figure 4.6. Consumers preference for the locally produced rice was highly influenced by taste and palatability of the rice (56%) while 19% indicated that it is readily available. On the other hand, majority (30%) of those who preferred the imported brands also attributed it to the tastes and palatability and 17% thinks it is clean, well-polished and do not contain stones or foreign materials.

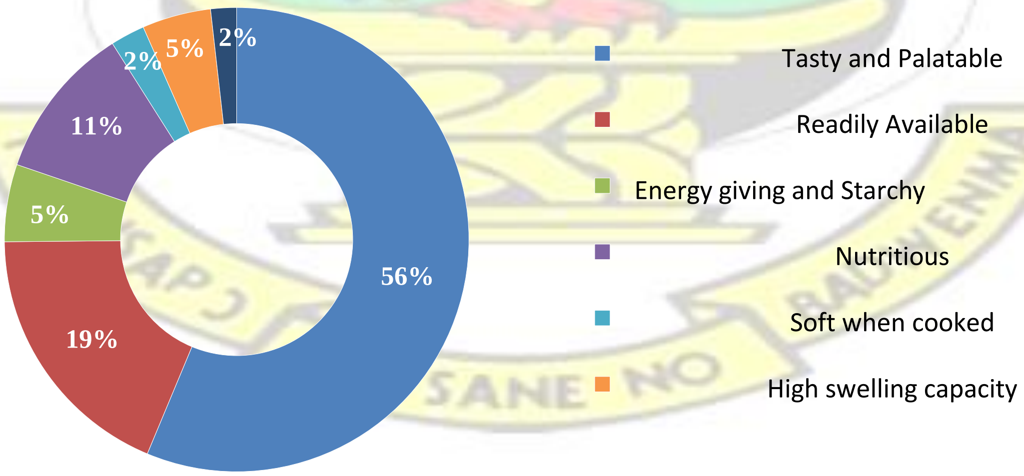


Figure 4.7: Reasons for preferring locally produced rice

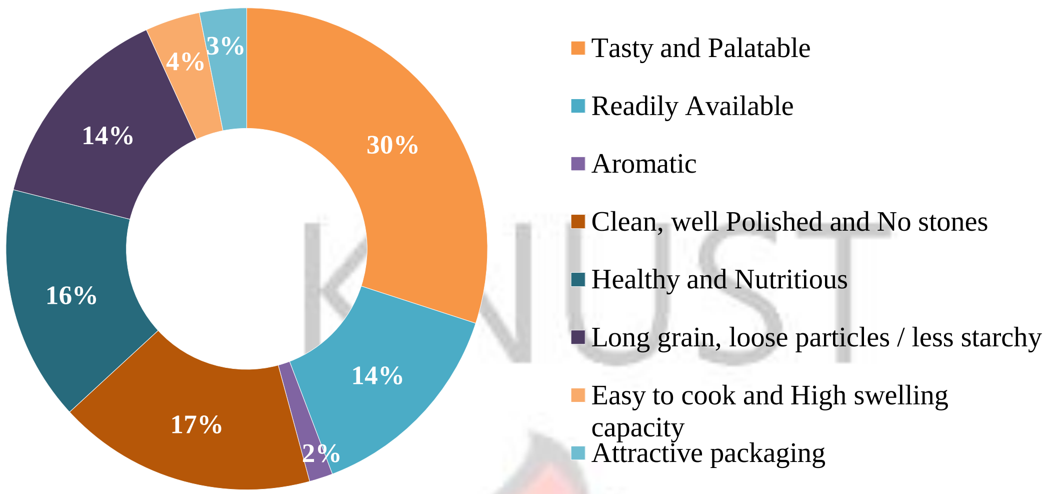


Figure 4.8: Reasons for preferring imported rice

Table 4.1 shows the various brands of imported rice varieties preferred by the survey respondents. Seven different imported rice brands from America and Asia were identified during the survey, majority (30.2%) of the consumers preferred aromatic/perfumed rice but could only give the brand name, 23.3% preferred Texas rice, followed by Royal feast rice 17.2%, 14.7% will chose Uncle Sam on any other day while 8.6% will go in for Sultana rice. The remaining three imported brands mentioned were Chicago rice 3.4%, Queens Pride 1.7% and Cindy rice 0.9%. Reasons given by respondents to their choices are shown in figure 4.8.

Table 4.1: Identified imported rice varieties (brands)

Varieties	Percentage (%)
Uncle Sam	14.7
Texas rice	23.3
Sultana	8.6
Royal feast	17.2
Queens Pride	1.7
Chicago Rice	3.4

Any Aromatic brand	30.2
Cindy rice	0.9

Based on the responses from the survey, all the six locally produce rice varieties identified and two highly preferred imported brands (aromatic and non-aromatic) were selected for the study. From table 4.1 above, Texas rice (Non-aromatic) and Royal feast rice (Aromatic) were selected and samples procured from the supermarket.

Table 4.2: Rice varieties identified

Local Rice (variety)	**Type**
Mandi	Non-aromatic
Gbewaa	Aromatic
Togo marshall	Aromatic
Red rice	Non-aromatic
AGRA rice	Aromatic
Sikamo	Non-aromatic
Imported Rice (brands)	
Texas rice	Non-aromatic
Royal feast rice	Aromatic

4.2.4 Knowledge on quality and standards

During the survey, respondents were asked if they had any standards in measuring quality regarding selection of which rice to buy/consume. Majority (60.8%) of the respondents answered yes while the remaining 39.2% said no. Those who responded yes had the following (Table 4.3) as their standards for quality measurement; aroma 24.2%, purity 23.0%, flavour 19.2%, colour 18.6%, texture 10.4% and 4.7% for swelling capacity.

Table 4.3: Standards (parameters) for measuring rice quality

Quality standard	**Responses**	
	Count (n)	Percent (%)
Purity	73	23.0
Colour	59	18.6
Aroma	77	24.2
Flavour	61	19.2
Texture	33	10.4
Swelling	15	4.7
Total	318	100.0

Sources of the locally produced rice from the survey shows that majority (39.5%) of these rice which are unbranded were supplied by the farmers while 34.9% was obtained from the local markets, 12.2% of moderately well packaged ones were obtained from selected sales outlets, 9.9% were obtained and consumed from farmers own farms and only 3.5% got their supplies from the supermarkets compared to the large quantities of imported varieties in these supermarkets.

Based on consumer standards, some perceived characteristics of the locally produced rice varieties were listed in the questionnaire for respondents to share their opinions by either agreeing or disagreeing with the listed parameters. The responses ranged from strongly agree to strongly disagree. Table 4.4 shows the perceptions of respondents based on their sensory attributes of the local rice varieties known to them.

Table 4.4: Respondents perception on quality/characteristics of locally produced rice

Parameter	Strongly Disagree (%)	Disagree (%)	Undecided (%)	Agree (%)	Strongly Agree (%)
Moderate Price	0.5	4.0	10.6	46.5	38.4
Tasty / Palatable	2.0	16.2	8.6	36.0	37.1
High Swelling Capacity	7.1	23.7	31.8	25.8	11.6
Readily Available	17.2	13.1	7.1	32.3	30.3
Odour	30.8	30.8	35.4	3.0	0.0
Well-Polished	10.1	45.5	18.2	21.7	4.5
Availability of Dirt	3.5	15.2	10.1	48.0	23.2
Long Shelf Life	4.0	18.2	42.4	25.3	10.1
Perfumed/aromatic	2.0	22.8	19.3	41.6	14.2
Hard	9.1	41.6	26.4	18.3	4.6
Sticky	1.0	7.6	26.9	45.2	19.3
Loose particles	5.1	17.7	47.0	26.3	4.0
White	2.5	31.5	14.7	45.2	6.1
Coloured/reddish brown	6.6	27.3	18.2	37.9	10.1
Short cooking time	1.0	10.2	32.5	49.2	7.1
High water holding capacity	14.7	17.3	39.6	21.3	7.1

Presence of foreign materials such as stones, weed seeds, husks, dirt etc. in the local rice were the most mentioned by the respondents even though they agreed that the local varieties are very tasty and nutritious (Table 4.4). The table shows 48.0% of respondents agreed to the availability of dirt in the locally produced milled rice as against 15.2% in disagreement, 46.5% agreed that the prices of locally produced rice are very moderate compared to its imported counterparts whiles only 4% disagreed with this assertion. In terms of taste or palatability, 37.1% strongly believed that the local rice is tasty while only 2% of the respondents strongly disagreed that the local rice is palatable, however, 30.8% strongly disagreed with the perception that the local rice has an unpleasant odour with only 3%agreeing to it. With consumer taste and preferences being skewed towards perfumed and long grain rice, the questionnaire also sought to know consumer's views on the local varieties in terms of aroma. 41.6% agreed that most of the local varieties in the market are aromatic (perfumed) while 22.8% disagreed, 45.2% believed the locally produced rice are sticky as a result of its high starch content while 41.6% disagreed with the perception that the local varieties are hard after cooking. Due to the sub-standard milling equipment used, the finished milled local rice is not well-polish, 45.5% of the respondents disagreed that the locally milled rice is well-polished as against 21.7% agreeing that it's wellpolished. Aside the red rice, which most consumers in the cities referred to as local rice, 45.2% as against 31.5% agrees that the local rice is white in colour and due to parboiling of rice particularly in the Northern sector of Ghana, 37.9% respondents thought the local rice is brownish white in colour while 27.3% disagrees with this perception.

4.2.5 Harvesting and Post-harvest Handling

Figure 4.9 represents the moisture content or timing at which paddy rice are usually harvested in the country. 30.8% of respondents were recorded as harvesting their paddy at a moisture content of 14%while 26.2% harvest theirs at 12% moisture content, same (26.2%) as those who harvest below 12% moisture contents and only 16.9% of farmers interviewed harvest their rice at 16% moisture content or above.

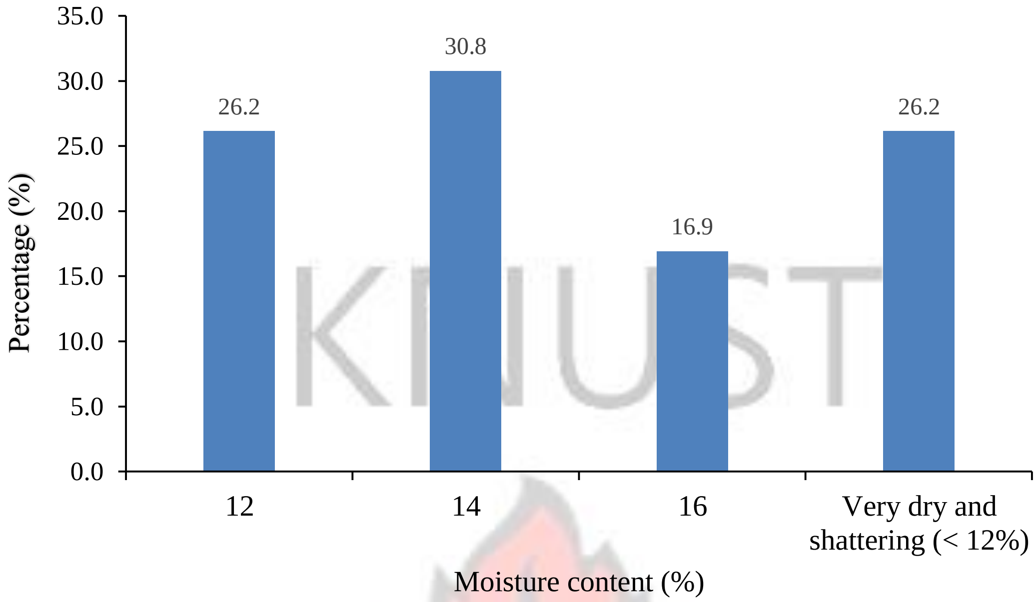


Figure 4.9 Moisture content at which harvesting is usually done

The presence of stones in local rice is currently at its minimum due to the current use of tarpaulins and other suitable materials as floor for paddy threshing. Figure 4.11 shows the percentage farmers (53%) using tarpaulins to thresh their rice while 37% still thresh their rice on the bare ground/soil, 7% uses mechanized rice threshers and 3% prefers the use of the Bambam threshing box which is commonly found in the southern parts of Ghana.

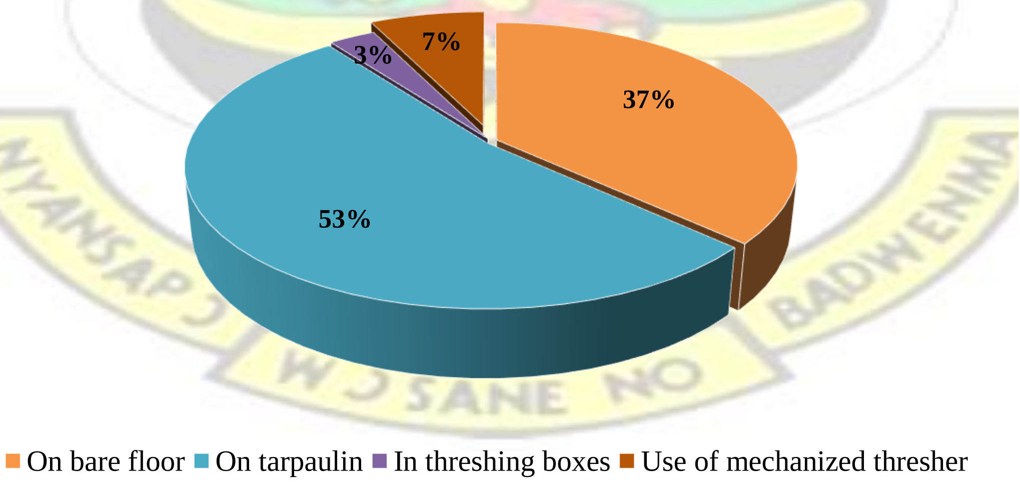


Figure 4.10 Methods of threshing rice locally

4.3 FUNCTIONAL PROPERTIES

4.3.1 Bulk Density

There were no significant differences ($p>0.01$) between the individual effects of bulk density of the rice varieties and storage period. The bulk density of the varieties ranged from 0.87 g/ml to 1.00g/ml while the storage periods ranged from 0.92 g/ml to 0.98 g/ml.

Interactive effects of the rice varieties stored for a period of four months for bulk density had no significant differences ($p>0.01$) but ranged from 0.84 g/ml to1.00 g/ml.

Table 4.5: Bulk density (g/ml) of the rice varieties

Rice Varieties/Brands	Storage Period				
	Month 1	**Month 2**	**Month 3**	**Month 4**	**Mean**
Gbewaa	1.00	1.00	0.92	1.00	0.98
AGRA Rice	0.98	0.95	0.91	0.97	0.95
Togo Marshall	1.00	1.02	1.00	0.97	1.00
Sikamo	0.95	0.95	0.92	1.00	0.96
Mandi	1.00	1.00	0.95	0.95	0.98
Red rice	0.91	0.88	0.84	0.84	0.87
Royal Feast	1.00	1.00	0.92	1.00	0.98
Texas Rice	1.00	1.00	0.91	0.97	0.97
Mean	0.98	0.98	0.92	0.96	

Hsd $_{(0.01)}$Storage period = 0.218
Hsd $_{(0.01)}$ Rice varieties = 0.352
Hsd $_{(0.01)}$Storage period *Rice vari
0.856

4.3.2 Foaming Capacity

There were significant differences ($p<0.01$) among the various rice varieties in terms of foaming capacity where the mean values ranged from 1.24ml/g to 4.85ml/g with Texas rice recording the least mean value of 1.24ml/g and Sikamo recording the highest of 4.85ml/g.

Statistically, there were significant differences ($p<0.01$) in foaming capacity among the storage duration periods. The mean values for the storage periods (from month 1 to month 4) ranged between 0.72ml/g as the least for Month 2 to 5.64ml/g as the highest for Month 4. However, Month 1 and Month 2 (0.75ml/g and 0.72ml/g respectively) showed no significant difference between their means compared to month 3 and month 4 (5.37ml/g and 5.64ml/g respectively).

The interaction effect of the rice varieties and storage periods showed significant differences ($p<0.01$). Sikamo recorded the highest foaming capacity of 13.04ml/g in its fourth month of storage, followed by Red rice with a foaming capacity of 9.62ml/g also in month 4 while Texas rice recorded the least foaming capacity of 0.25ml/g after just two months of storage.

Table 4.6: Foaming capacity (ml/g) of the rice varieties

Rice Varieties/Brands	**Storage Period**				
	Month 1	**Month 2**	**Month 3**	**Month 4**	**Mean**
Gbewaa	0.50	1.00	4.35	4.55	2.60
AGRA Rice	0.50	1.00	4.35	4.35	2.55
Togo Marshall	1.00	0.50	8.70	0.49	2.67
Sikamo	1.00	1.00	4.35	13.04	4.85
Mandi	0.50	0.50	4.35	8.70	3.51
Red rice	1.00	0.50	4.35	9.62	3.87
Royal Feast	1.00	1.00	8.33	4.35	3.67
Texas Rice	0.50	0.25	4.17	0.05	1.24
Mean	0.75	0.72	5.37	5.64	

$Hsd_{(0.01)}$Storage period = 0.470
$Hsd_{(0.01)}$ Rice varieties = 0.758
$Hsd_{(0.01)}$Storage period *Rice varieties = 1.845

4.3.3 Oil Absorption Capacity

There were significant differences ($p<0.01$) among the rice varieties in terms of Oil Absorption Capacity. The least oil absorbing capacity of 68.00ml/g was recorded by Red rice which was significantly different from Togo marshal with the highest oil absorption capacity of 91.00ml/g.

There were significant differences ($p<0.01$) in the oil absorption capacities of the rice varieties among the storage period. The mean values for the storage months ranged from 69.25ml/g to 84.75ml/g with the first month of storage recording the highest oil absorption capacity and the least by the fourth month.

The interaction effect of the rice varieties and storage periods showed significant differences ($p<0.01$) in their oil absorption capacities. Togo marshal in its first month of storage recorded the highest Oil absorption capacity of 138.00ml/g, followed by Mandi (94.00ml/g) in month 4. The least Oil absorption capacity was recorded by Togo marshal (60.00ml/g) and Sikamo (60.00ml/g) all in the fourth and final month of storage.

Table 4.7: Oil absorption capacity (ml/g) of the rice varieties

Rice Varieties/Brands	**Storage Period**				
	Month 1	**Month 2**	**Month 3**	**Month 4**	**Mean**
Gbewaa	72.00	92.00	88.00	68.00	80.00
AGRA Rice	78.00	64.00	82.00	72.00	74.00
Togo Marshall	138.00	88.00	78.00	60.00	91.00
Sikamo	82.00	70.00	86.00	60.00	74.50
Mandi	92.00	70.00	68.00	94.00	81.00
Red rice	72.00	72.00	66.00	62.00	68.00
Royal Feast	74.00	68.00	90.00	76.00	77.00
Texas Rice	70.00	84.00	82.00	62.00	74.50
Mean	84.75	76.00	80.00	69.25	

Hsd $_{(0.01)}$Storage period = 6.223
Hsd $_{(0.01)}$ Rice varieties = 10.040
Hsd $_{(0.01)}$Storage period *Rice varieties = 24.436

4.3.4 Water Absorption Capacity

There were significant differences (p<0.01) among the rice varieties in terms of water absorption capacity where red rice recorded the highest mean value of 134.00ml/g while AGRA rice recorded the least mean value of 73.50ml/g.

There were no significant differences (p>0.01) in the water absorption capacities among the second, third and fourth months of storage which recorded mean values of 91,33ml/g, 91,00ml/g and 91.00ml/g respectively but however, the first month recorded a mean value of 69.50ml/g which was significantly different (p<0.01) from the others.

The interaction effect of the rice varieties and their storage periods showed some significant differences (p<0.01) in the water absorption capacities of the rice samples. Red rice recorded the highest water absorption capacities of 152.00ml/g, 150.00ml/g, 148.00ml/gin the first, fourth and second months of storage respectively, as well as Togo marshal (140.00ml/g) in its third month of storage. AGRA rice recorded the least water absorption capacity of 48.00ml/g in its first month of storage.

Table 4.8: Water absorption capacity (ml/g) of the rice varieties

Rice Varieties/Brands	Storage Period				
	Month 1	Month 2	Month 3	Month 4	Mean
Gbewaa	62.00	86.00	74.00	88.00	77.50
AGRA Rice	48.00	80.00	86.00	80.00	73.50
Togo Marshall	50.00	82.67	140.00	90.00	90.67
Sikamo	62.00	76.00	82.00	82.00	75.50
Mandi	64.00	88.00	74.00	84.00	77.50
Red rice	152.00	148.00	86.00	150.00	134.00
Royal Feast	58.00	98.00	92.00	74.00	80.50
Texas Rice	60.00	72.00	94.00	80.00	76.50
Mean	69.50	91.33	91.00	91.00	

Hsd $_{(0.01)}$Storage period= 5.913
Hsd $_{(0.01)}$ Rice varieties= 9.540
Hsd $_{(0.01)}$Storage period *Rice varieties= [illegible]

4.3.5 Swelling Capacity

There were significant differences ($p<0.01$) among the rice varieties in terms of Swelling capacity where mean values ranged from 5.19g/ml to 6.56g/ml. Statistically there were no significant difference between Sikamo, Red rice and Royal feast rice which recorded 6.56g/ml, 6.39g/ml and 6.336g/ml respectively. However, the Mandi local variety recorded the least swelling capacity with 5.19g/ml which was significantly different from the others.

Statistically there were no significant differences (p>0.01) in the mean values of swelling capacity for the four months duration storage period. However, their mean values ranged from 5.73g/ml to 6.13g/ml.

The interaction effect of the rice varieties and their storage periods showed significant differences (p<0.01) in their swelling abilities. Red rice recorded the highest Swelling capacity of 7.28g/ml in the third month of storage, followed by Royal feast 6.87g/ml also in the third month while the variety with the least Swelling capacity of 3.73g/ml was Mandi and this was recorded in the Fourth month of storage.

Table 4.9: Swelling Capacity (g/ml) of the rice varieties

Rice Varieties/Brands	**Storage Period**				
	Month 1	**Month 2**	**Month 3**	**Month 4**	**Mean**
Gbewaa	5.57	5.68	5.82	6.02	5.77
AGRA Rice	5.00	6.70	4.89	5.29	5.47
Togo Marshall	5.70	6.16	5.63	6.27	5.94
Sikamo	6.71	6.33	6.64	6.55	6.56
Mandi	4.85	6.24	5.93	3.73	5.19
Red rice	6.62	6.43	7.28	5.24	6.39
Royal Feast	6.17	5.65	6.87	6.75	6.36
Texas Rice	6.00	5.32	5.97	5.96	5.81
Mean	5.83	6.06	6.13	5.73	

Hsd $_{(0.01)}$Storage period = 0.696
Hsd $_{(0.01)}$ Rice varieties = 1.122
Hsd $_{(0.01)}$Storage period *Rice varieties = 2.731

4.4 SENSORY PROPERTIES

4.4.1 Aroma

There were significant differences ($p<0.05$) among the rice varieties in terms of Aroma. Gbewaa rice recorded the highest score of 4.22, followed by Royal feast (4.12) and AGRA rice (3.95) while the least score of 3.00 was recorded by Red rice.

There were no significant differences ($p>0.05$) in Aroma among the four different months of storage periods. Their mean values however ranged from 3.47 to 3.78 during the storage period.

The interaction effect of the sampled rice varieties and their storage periods showed significant differences ($p<0.05$) in their Aromatic properties. Royal feast and Gbewaa rice recorded the highest score of 4.53 in their second and third months of storage, respectively. The least score of 2.27 was recorded by Red rice which was significantly different from the others.

Table 4.10: Sensory attribute of the rice varieties on Aroma

Rice Varieties/Brands	Storage Period				
	Month 1	**Month 2**	**Month 3**	**Month 4**	**Mean**
Gbewaa	4.45	4.07	4.53	3.80	4.22
AGRA rice	3.73	3.73	4.20	4.13	3.95
Togo Marshall	3.53	3.40	4.33	3.53	3.70
Sikamo	3.13	3.13	3.47	3.53	3.32
Mandi	3.67	2.67	3.00	3.20	3.13
Red Rice	3.73	3.07	2.93	2.27	3.00
Royal Feast	4.00	4.53	4.07	3.87	4.12
Texas Rice	3.46	3.93	3.67	3.40	3.62
Mean	3.72	3.57	3.78	3.47	

$Hsd_{(0.05)}$Storage period = 0.465
$Hsd_{(0.05)}$ Rice varieties = 0.740
$Hsd_{(0.05)}$Storage period *Rice varieties = 1.743

4.4.2 Taste

There were significant differences (p<0.05) among the rice varieties in terms of Taste preferences. Statistically, the preference for Gbewaa (4.30) which recorded the highest score was not significantly different from Royal feast rice (4.11) but significantly different (p<0.05) from the others. The variety with the least score for Taste preference was recorded by Mandi rice (3.03).

The mean values for Taste preference for the four months storage periods ranged from 3.18 to 3.82. There were no significant differences (p>0.05) between the first, second and third month of storage period but there was a significant difference (p<0.05) recorded in the fourth month with the least mean score value of 3.18.

The interaction effect of the various rice varieties with their months of storage showed significant differences (p<0.05). Royal feast recorded the highest score of 4.47 in both the second and third month of storage which was not significantly different (p>0.05) from Gbewaa rice which also recorded 4.47 in the third month and 4.40 in its first month of storage but they were significantly different from the other varieties and storage periods. The least score (2.27) for taste was recorded by Red rice.

Table 4.11: Sensory attribute of the rice varieties on Taste

Rice Varieties/Brands	Storage Period				
	Month 1	**Month 2**	**Month 3**	**Month 4**	**Mean**
Gbewaa	4.40	4.20	4.47	4.13	4.30
AGRA rice	4.27	3.53	3.67	3.60	3.77
Togo Marshall	3.13	3.53	4.13	3.13	3.48
Sikamo	3.67	3.60	3.20	3.07	3.38
Mandi	2.40	3.87	3.07	2.93	3.03

Red rice	4.27	3.40	2.93	2.27	3.25
Royal Feast	4.20	4.47	4.47	3.27	4.10
Texas rice	4.20	3.93	4.00	3.07	3.80
Mean	3.82	3.82	3.74	3.18	

Hsd $_{(0.05)}$Storage period = 0.466
Hsd $_{(0.05)}$ Rice varieties = 0.743
Hsd $_{(0.05)}$Storage period *Rice varieties = 1.748

4.4.3 Colour

There were significant differences ($p<0.05$) among the rice varieties in terms of Colour preferences where the mean values ranged from 3.15 to 4.53. Statistically there were no significant differences ($p>0.05$) among Royal feast (4.53), Texas rice (4.48) and Gbewaa rice (4.43) but they were significantly different from the others and Red rice recorded the least mean score of 3.15.

The mean values for colour preferences during the four months of storage periods ranged from 3.65 to 4.08. There were significant differences ($p<0.05$) among the Months of storage. The fourth month recorded the least mean value of 3.65 while the third and first months had the highest mean scores of 4.08 and 4.04 respectively.

The interaction effect of the various rice varieties with their months of storage showed some significant differences ($p<0.05$). Texas rice recorded the highest score of 4.87 in the second month of storage followed by Royal feast at 4.80 in the second month, 4.73 in the third month and Gbewaa rice recording 4.73 in both the second and third month of storage and these three varieties were not significantly different ($p>0.05$) from each other but significantly different from the others. The least score of 2.67 for colour was recorded by Red rice in its third month of storage.

Table 4.12: Sensory attribute of the rice varieties on Colour

Rice Varieties/Brands	**Storage Period**				**Mean**
	Month 1	**Month 2**	**Month 3**	**Month 4**	
Gbewaa	4.60	4.73	4.73	3.66	4.43
AGRA rice	4.40	3.60	4.47	4.00	4.12
Togo Marshall	3.60	3.47	4.40	3.73	3.80
Sikamo	3.13	3.27	4.00	3.47	3.47
Mandi	3.60	3.40	3.13	3.33	3.37
Red rice	3.93	3.13	2.67	2.87	3.15
Royal Feast	4.40	4.80	4.73	4.20	4.53
Texas rice	4.67	4.87	4.47	3.93	4.48
Mean	4.04	3.91	4.08	3.65	

Hsd $_{(0.05)}$Storage period = 0.422
Hsd $_{(0.05)}$ Rice varieties = 0.672
Hsd $_{(0.05)}$Storage period *Rice varieties = 1.682

4.4.4 Flavour

There were no significant differences (p>0.05) between Royal feast (4.05) and the Gbewaa rice (3.95) but they were significantly different from the others. However, Royal feast (4.05) recorded the highest score/preference while Red rice recorded the least score of 3.15. There were no significant differences ($p>0.05$) in the mean values for Flavour during the four months periods of storage. However, the mean values ranged from 3.38 to 3.56 after the four months of storage.

The interaction effect of the various rice varieties with their months of storage showed some significant differences ($p<0.05$). Texas rice recorded the highest score of 4.33 in the first month of storage followed by Texas and Royal feast rice with a score of 4.20 in their second and third months of storage respectively. Red rice recorded the least score of 2.60in the fourth month of storage.

Table 4.13: Sensory attribute of the rice varieties on Flavour

Rice Varieties/Brands	**Storage Period**				
	Month 1	**Month 2**	**Month 3**	**Month 4**	**Mean**
Gbewaa	4.13	3.73	4.07	3.87	3.95
AGRA rice	3.47	3.47	3.47	4.07	3.62
Togo Marshall	3.53	3.13	3.00	3.33	3.25
Sikamo	3.00	2.87	3.67	3.00	3.13
Mandi	2.73	2.93	3.47	3.00	3.03
Red rice	2.93	3.13	3.00	2.60	2.92
Royal Feast	3.87	4.13	4.20	4.00	4.05
Texas rice	4.33	4.20	3.60	3.13	3.82
Mean	3.50	3.45	3.56	3.38	

Hsd $_{(0.05)}$Storage period = 0.502
Hsd $_{(0.05)}$ Rice varieties = 0.800
Hsd $_{(0.05)}$Storage period *Rice varieties = 1.882

4.4.5 Texture

There were significant differences (p<0.05) among the rice varieties in terms of Texture where the mean values ranged from 3.22 to 3.93. Gbewaa with a mean score of 3.93 and Royal feast rice with a score of 3.88 were the varieties with the highest mean score and not statistically different from each other but they were significantly different from the others. Red rice recorded the least preferred in terms of texture with a mean score of 2.83.

There were no significant differences (p>0.05) in the mean values for the four months storage periods of all the rice varieties. However, the mean values ranged from 3.27 to 3.62 after the fourth month of storage.

The interaction effect of the various rice varieties with their months of storage showed significant differences (p<0.05). Royal feast and Gbewaa rice were not significantly different (p>0.05) from each other with score values of 4.33 and 4.27 recorded in the third and first months of storage respectively. They were however significantly different (p<0.05) from the other varieties and their interactions with the storage periods. Red rice recorded the least score of 2.40 in the fourth month of storage and was preceded by Texas rice with a score of 2.67 in the fourth month.

Table 4.14: Sensory attribute of the rice varieties on Texture

Rice Varieties/Brands	Storage Period				Mean
	Month 1	Month 2	Month 3	Month 4	
Gbewaa	4.27	3.87	4.00	3.60	3.93
AGRA rice	3.80	3.53	3.47	3.80	3.65
Togo Marshall	3.60	3.53	3.67	3.73	3.63
Sikamo	3.40	3.07	3.27	3.27	3.25
Mandi	3.00	3.53	3.33	3.00	3.22

Red rice	3.07	2.80	3.07	2.40	2.83
Royal Feast	3.60	3.93	4.33	3.67	3.88
Texas rice	4.13	3.87	3.80	2.67	3.62
Mean	3.61	3.52	3.62	3.27	

Hsd $_{(0.05)}$Storage period = 0.491
Hsd $_{(0.05)}$ Rice varieties = 0.781
Hsd $_{(0.05)}$Storage period *Rice varieties = 1.838

4.4.6 Hardness

There were significant differences ($p<0.05$) among the rice varieties in terms of grain Hardness where the mean values ranged from 2.93 to 3.88. Gbewaa recorded the highest mean score of 3.88, followed by Royal feast (3.80), Texas rice (3.65) and Togo marshal (3.63). The Mandi variety was the least preferred in terms of hardness with a mean score of 2.93.

There were significant differences ($p<0.05$) in the mean values for the four months storage periods of all the rice varieties/brands. The mean values ranged from 3.07 to 3.73 with the highest mean score recorded in the third month and the least score in the fourth month.

The interaction effect of the various rice varieties with their months of storage showed some significant differences ($p<0.05$). Royal feast and Texas rice recorded the highest score value of 4.20 in the first month of storage and this gradually declined as the storage period increased. Mandi variety in the fourth and final months of storage recorded the least score of 2.33.

Table 4.15: Sensory attribute of the rice varieties on Hardness

Rice Varieties/Brands	Storage Period				
	Month 1	**Month 2**	**Month 3**	**Month 4**	**Mean**
Gbewaa	3.53	4.07	3.93	4.00	3.88
AGRA rice	3.40	3.20	3.73	3.60	3.48

Togo Marshall	3.73	3.53	4.00	3.27	3.63
Sikamo	2.93	3.20	3.87	3.00	3.25
Mandi	3.27	3.27	2.87	2.33	2.93
Red rice	3.53	3.07	3.80	2.60	3.25
Royal Feast	4.20	4.13	3.67	3.20	3.80
Texas rice	4.20	3.93	3.93	2.53	3.65
Mean	3.60	3.55	3.73	3.07	

Hsd $_{(0.05)}$Storage period = 0.519
Hsd $_{(0.05)}$ Rice varieties = 0.826
Hsd $_{(0.05)}$Storage period *Rice varieties = 1.43

4.4.7 Stickiness

The mean score values for the rice varieties in terms of Stickiness ranged between 2.70 to 3.78. With the exception of the Red rice, there were no significant differences (p>0.05) among the other rice varieties in terms of Stickiness with mean score values ranging from 3.43 for Mandi to 3.78for Royal feast rice. Red rice recorded the least mean value of 2.70 and was the only variety that was significantly different from the others.

There were some significant differences (p<0.05) in the mean values for the four months storage periods of all the rice varieties/brands. The mean values ranged from 3.25 to 3.68 with the highest mean scores recorded in the first and second months of storage while the least mean score value was recorded in the fourth month.

The interaction effect of the various rice varieties with their months of storage showed significant differences (p<0.05). Gbewaa and Texas rice recorded the highest score value of 4.20 in their second and first months of storage respectively which was not significantly different (p>0.05) from the third month of Gbewaa, second month of Texas and the third month of Togo marshal rice varieties (4.13). These were significantly different from the other varieties.

Red rice recorded the least score value of 2.07in the fourth and final months of storage.

Table 4.16: Sensory attribute of the rice varieties on Stickiness

Rice Varieties/Brands	Storage Period Month 1	Month 2	Month 3	Month 4	Mean
Gbewaa	3.47	4.20	4.13	3.27	3.77
AGRA rice	3.73	3.53	3.73	4.07	3.77
Togo Marshall	3.73	3.67	4.13	3.53	3.77
Sikamo	3.47	3.53	3.80	3.47	3.57
Mandi	3.80	3.67	3.53	2.73	3.43
Red rice	3.13	3.13	2.47	2.07	2.70
Royal Feast	3.93	3.60	3.93	3.67	3.78
Texas rice	4.20	4.13	3.40	3.20	3.73
Mean	3.68	3.68	3.64	3.25	

Hsd $_{(0.05)}$Storage period = 0.522
Hsd $_{(0.05)}$ Rice varieties = 0.831
Hsd $_{(0.05)}$Storage period *Rice varieties =
1 .956

4.4.8 Loose particles

There were no significant differences (p>0.05) among the rice varieties in terms of loosely disperse rice grains/particle where mean score values ranged from3.27 to 3.87.

The mean values for the storage months ranged from 3.22 to 3.83. Month 1 and Month 2 were not significantly different from each other with mean values of 3.83 and 3.75 respectively but they were significantly different (p<0.05) from Month 3 and Month 4 with mean values of 3.22 and 3.28 respectively. The highest mean was recorded in the first month while the least was in the third month of storage.

The interaction effect of the rice varieties and their storage periods showed some significant differences ($p<0.05$). Royal feast recorded the highest Loose particle score of4.60in its first month storage period, followed by Texas rice with a score of 4.47 in the second month. Gbewaa, Togo marshal and Red rice recorded 3.07, 2.73 and 2.80 respectively in their second month of storage while Sikamo, Royal feast and Texas rice also recorded score values of 2.73, 3.00 and 2.87 respectively in their third month of storage but these six varieties out of the eight samples were statistically not different ($p>0.05$) from each other. Togo marshal and Sikamo recorded the least values (2.73) for loose particles in the second and third months of storage respectively.

Table 4.17: Interaction table of the rice varieties on Loose particles

Rice Varieties/Brands	Storage Period				
	Month 1	**Month 2**	**Month 3**	**Month 4**	**Mean**
Gbewaa	3.73	3.53	3.07	3.53	3.47
AGRA rice	3.13	3.40	3.47	3.67	3.47
Togo Marshall	3.53	3.27	2.73	3.53	3.27
Sikamo	3.87	3.80	3.20	2.73	3.40
Mandi	3.60	3.47	3.27	3.00	3.33
Red rice	3.87	3.67	2.80	3.93	3.57

Royal Feast	4.60	4.40	3.47	3.00	3.87
Texas rice	4.33	4.47	3.73	2.87	3.85
Mean	3.83	3.75	3.22	3.28	

Hsd $_{(0.05)}$ Storage period = 0.528
Hsd $_{(0.05)}$ Rice varieties = 0.840
Hsd $_{(0.05)}$ Storage period *Rice varieties = 1.977

4.5 PROXIMATE ANALYSIS

4.5.1 Moisture

There were significant differences ($p<0.01$) among the rice varieties in terms of moisture where the mean values ranged from 3.83% to 6.33% before the commencement of storage. Royal feast rice recorded the highest mean of 6.33% which was significantly different from Mandi, the rice with the lowest moisture content of 3.83%.

After four months storage of the rice samples, there were significant differences ($p<0.01$) in moisture contents between the various identified rice varieties with mean values ranging from 6.83% as the highest for Royal feast to 4.50% being the least for the Gbewaa rice variety.

4.5.2 Ash

There were no significant differences ($p>0.01$) in Ash content among the rice varieties where the mean values ranged from 0.67% to 1.33% before storage of the samples.

After four months of storing all the rice varieties under same conditions, there were no significant differences ($p>0.01$) among the mean values for Ash contents of each rice variety. The ash content values ranged from 0.09% to 0.43% after a four month storage period.

4.5.3 Protein

There were significant differences ($p<0.01$) among the rice varieties in terms of protein before the samples were stored, where the mean values ranged from 7.68% to 9.87%. During that period, AGRA rice recorded the highest mean value of 9.87% which was significantly different from Sikamo, the variety with the least protein content of 7.68%.

After four months of storage of the rice samples, there were significant differences ($p<0.01$) among the various rice varieties in terms of protein content with mean values that ranged from 6.04% as the least, recorded by Red rice and the highest value of 10.63% was recorded by the Togo marshal variety. The highest mean value recorded by Togo marshall was followed Royal feast, Sikamo, Mandi, Gbewaa and AGRA rice varieties with values of 9.38%, 8.55%, 7.92%, 7.50%, 7.29% and 7.29% respectively at the end of the four months storage. However, these six varieties (except Togo marshall) were not significantly different ($p>0.01$) from each other. Red rice recorded the least value of 6.04% in Protein content at the end of storage.

Table 4.18: Proximate composition of rice varieties before and after storage

Rice Varieties/Brands	Moisture (%)		Ash (%)		Protein (%)	
	BS	AS	BS	AS	BS	AS
Gbewaa	4.67^{ab}	4.50^{c}	0.83^{a}	0.43^{a}	8.99^{abc}	7.29^{ab}
AGRA rice	4.67^{ab}	5.50^{bc}	0.83^{a}	0.15^{a}	9.87^{a}	7.29^{ab}
Togo marshall	5.67^{ab}	5.00^{c}	0.67^{a}	0.29^{a}	8.85^{bc}	10.63^{a}
Sikamo	5.50^{ab}	5.66^{abc}	1.00^{a}	0.37^{a}	7.68^{d}	7.92^{ab}

Mandi	3.83^{b}	5.17^{bc}	1.00^{a}	0.09^{a}	8.85^{bc}	7.50^{ab}
Red rice	6.00^{ab}	6.33^{ab}	1.33^{a}	0.36^{a}	8.27^{cd}	6.04^{b}
Royal feast	6.33^{a}	6.83^{a}	1.17^{a}	0.17^{a}	9.29^{ab}	8.55^{ab}
Texas rice	6.00^{ab}	5.33^{bc}	0.83^{a}	0.21^{a}	9.43^{ab}	9.38^{ab}

*BS – Before Storage, *AS – After Storage

*Values with the same alphabetical superscript within columns are not significantly different at 1%

4.5.4 Fat

There were no significant differences (p>0.01) among the rice varieties in terms of Fat contents where the mean values ranged from 1.17% to 2.91% before storage of the samples.

After the four months of storage period of the rice varieties, there were significant differences (p<0.01) recorded among the rice varieties in terms of Fat contents. Mean values ranged from 0.50% to 2.67% with Togo marshall and AGRA rice recording the same highest value of 2.67% followed by Red rice with a value of 2.50% which was not statistically different from the AGRA and Togo marshall. The variety with the least Fat content at the end of the four months storage period was Gbewaa with a mean value of 0.50% which was significantly different (p<0.01) from the other varieties.

4.5.5 Fibre

There were no significant differences (p>0.01) among the rice varieties in terms of Fibre contents where the mean values ranged from 1.27% to 2.91% before the storage of the rice varieties/samples.

There were significant differences (p<0.01) among the rice varieties in terms of fibre contents after the four months storage and an observation of a generally decreases in fibre contents of the rice varieties. The mean values recorded ranged from 0.53% to 2.57% with Red rice recording the highest mean in fibre content of 2.57%, followed by Texas rice with a value of 2.22%, The varieties with the least fibre contents after the four months of storage were Mandi and AGRA rice with both recording 0.53% fibre content, followed by Royal feast at 0.57% and they were significantly different (p<0.01) from the others (Table 4.19).

4.5.6 Carbohydrate (NFE)

There were no significant differences (p>0.01) among the rice varieties in terms of Carbohydrate where the mean values ranged from 78.61% to 82.19% before the storage of the rice varieties/samples.

There were significant differences (p<0.01) among the rice varieties in terms of carbohydrate contents after the period of storage where the mean values ranged from 79.77% to 85.38%, with Mandi recording the highest (85.38%), followed by Gbewaa (85.23%) which was not significantly different (p>0.01) from the Mandi. Togo marshall variety recorded the least in carbohydrate contents (79.77%) at the end of the storage period of four months.

Table 4.19: Proximate composition of rice varieties before and after storage

Rice Varieties/Brands	Fat (%)		Fibre (%)		Carbohydrate (%)	
	BS	AS	BS	AS	BS	AS
Gbewaa	1.50^{a}	0.50^{d}	2.37^{a}	2.05^{b}	81.63^{a}	85.23^{a}
AGRA rice	1.17^{a}	2.67^{a}	1.27^{a}	0.53^{d}	82.19^{a}	83.86^{ab}
Togo marshall	1.77^{a}	2.67^{a}	1.66^{a}	1.64^{c}	81.38^{a}	79.77^{c}

Sikamo	1.85^{a}	1.17^{c}	2.82^{a}	0.69^{d}	81.14^{a}	84.18^{ab}
Mandi	2.91^{a}	1.33^{bc}	1.67^{a}	0.53^{d}	81.74^{a}	85.38^{a}
Red rice	2.19^{a}	2.50^{a}	2.41^{a}	2.57^{a}	79.79^{a}	82.19^{abc}
Royal feast	1.39^{a}	1.17^{c}	1.36^{a}	0.57^{d}	80.47^{a}	82.72^{abc}
Texas rice	2.22^{a}	1.83^{b}	2.91^{a}	2.22^{ab}	78.61^{a}	81.03^{bc}

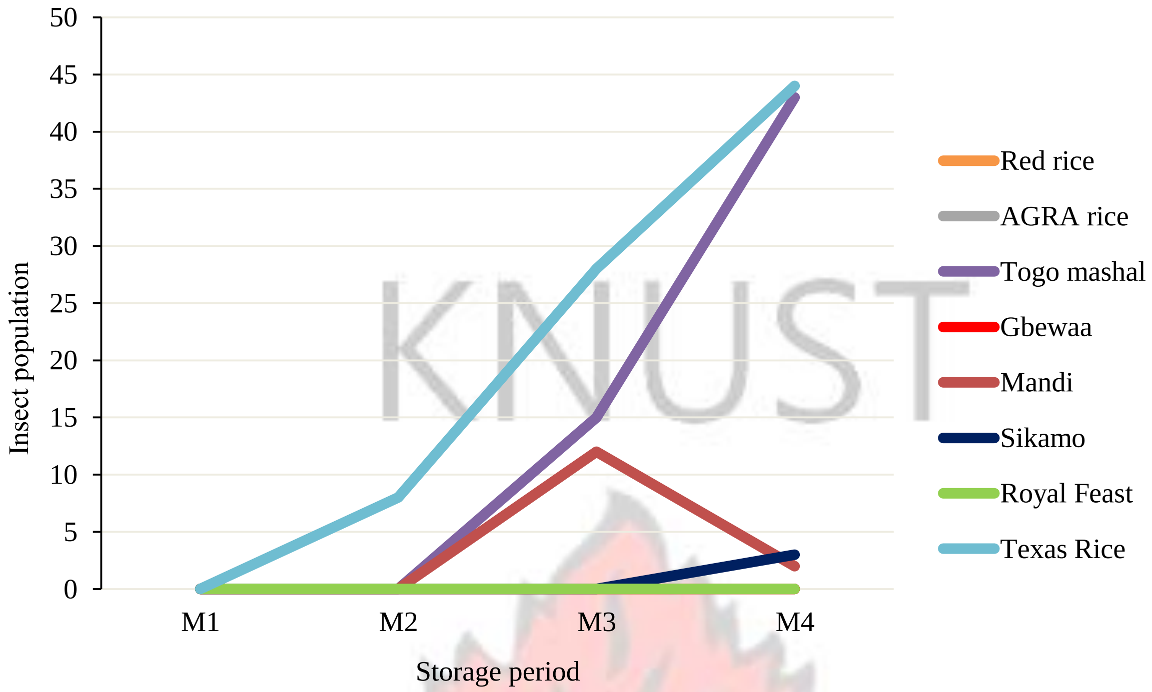
*BS – Before Storage, *AS – After Storage

*Values with the same alphabetical superscript within columns are not significantly different at 1%

4.6 SUSCEPTIBILITY TO INSECT INFESTATION

At the end of every 30 days of storage from day one to the end of the four months of storage periods, 2g of each rice sample was assessed for storage insect's infestation. The first month recorded zero at the end of the 30days of storage, however, some insect activities were observed at the end of the second month (60days of storage) but these were seen only in the Texas rice variety/brand. A total of 8 rice weevils were identified in the Texas rice while all the other varieties still remain devoid of insects.

There were significant differences in insect infestation among the varieties in the third month of storage. Three out of the eight rice varieties/brand stored experienced some form of insect infestation; Texas (28) had the highest number of insects, followed by Togo marshall (15) and then Mandi (12). The insect population/infestation increased in number at the end of the fourth and final month of storage with Sikamo variety recording its first infestation in the fourth month (3 rice weevils)while Togo marshall increased to 43, Texas rice (44) and Mandi recorded the least of 2 rice weevils. The remaining four varieties (Red rice, Gbewaa, Royal feast and AGRA rice) did not record any form of insect infestations even though they were all stored under the same environmental and storage conditions with the other four affected varieties/brands.



**M1 – First month, M2 – Second month, M3 – Third month, M4 – Fourth month* Figure 4.11: Insects infestation and population during storage

CHAPTER FIVE

5.0 DISCUSSION

5.1 FIELD SURVEY

5.1.1 Background Information on Respondents

From the result, there were more males into rice production than females (Figure 4.1) in Ghana and this is usually due to the perception that rice production is very difficult and labour intensive compared to other cereal crops. However, most of its harvest and postharvest activities are done by females. Another factor mostly in the Northern region has to do with land ownership where all lands are owned by the men and the women are relegated to the household chores. The women only assist in their husbands farms during planting, harvesting and processing. However, females dominate the aggregation, processing and trading of both paddy and milled rice.

The study also revealed that 31% of the respondents had no formal education and the farmers or producers made up the majority while rice consumers recorded the highest in formal education up to the basic level. This might be as a result of most consumers being located in the urban cities compared with the vast number of farmers located in rural deprived areas who were only engaged in the farming as their source of livelihood.

5.1.2 Rice Consumption and consumer preference

Rice is steadily taking over as the main staple food in most Ghanaian households instead of maize and tubers as traditionally used to be (MoFA, 2000). A lot of factors can be assigned to this drift in meal preference such as ease of availability and comparatively easy to cook/prepare. Sources of milled rice for the retail market mainly do come locally from the farming centres throughout the country and about 50% from importation. The largest producer locally being the Northern region, followed by Volta, Upper East region then the others. The varieties produced depend on the production ecology and the market or consumer preference.

According to the result, close to 100% (99.5%) of those interviewed indicated they consume rice which affirms the above assertion that rice is gradually taking over as the main staple food in Ghana. Only 10.1% out of these respondents claimed they do not consume locally produced rice while remaining 89.9% patronise produce/made in Ghana rice. However, it was interesting to know that majority of the consumers preferred the locally produced varieties as shown in figure 4.4 compared to the imported brands. Northern region according to the survey result recorded the highest consumption of locally produced rice, followed by Ashanti region with Greater Accra recording the least but in terms of the imported varieties/brands, Greater Accra region is the highest consumer, followed by Ashanti and then Northern region (Figure 4.6). The educational background and social status of consumers in these regions might have influenced their rice consumption preferences (Bam *et al.*, 1998).

As part of the study, commercial locally produced and imported rice varieties were to be identified through the interviewing of rice producers, consumers, traders, processors and other stakeholders. Six locally produced varieties (Figure 4.5) were identified as the commonly produced and consumed varieties in the three study locations/regions. Some reasons given for their preferences were nutritious taste, aroma, high yielding, long grain and cooking quality.

5.1.3 Reasons for consumer preference of rice (local or imported)

Consumer's preference for locally produced or imported rice was greatly influenced by their geographical locations, educational background and the ease of accessibility of the rice. The results as indicated in figures 4.7 and 4.8, revealed that majority of the consumers selected their rice type based on the taste and palatability for both the imported and the locally produced rice varieties. However, while nutrition was the third highest rated reason given by respondents for their preferences of both the imported and local rice varieties, well-polished, clean grains devoid of stones and foreign materials were other strong reasons given by consumers with preference for the imported rice varieties/brands. This is mainly attributed to the production and postharvest activities of farmers in mostly the Northern part of Ghana where majority of the rice is produced locally. Threshing on bare floors over-drying of grains and poor agronomic practices are key factors resulting in the poor colour, presence of foreign materials, admixtures and breakages in the local rice varieties making it physically unappealing for consumption. Aroma was also a key factor in the choice of imported rice variety over the locally produced rice varieties and most consumers interviewed in the Greater Accra region only knew the Red rice to the local rice but had no idea that there were also locally produced aromatic white rice in Ghana.

There are over 50 and more rice varieties being produced in Ghana for consumption and the six identified during storage were the most frequently produced and commercial (consumed) rice varieties found in the Ghanaian markets and individual households. They were; Gbewaa, Togo Marshall, AGRA rice (all aromatic varieties) and Mandi, Sikamo, Red rice (all non-aromatic varieties). More imported rice brands were identified during the survey but due to the large sample size or experimental treatments, the aromatic (Royal feast) and non-aromatic (Texas rice) brands with the highest frequencies were selected for the study (Table 4.2).

5.1.4 Knowledge on quality and standards

There is the need to substitute imported rice brands/varieties in Ghana with the locally produced rice varieties, however, this requires improving the quality of the latter to standards set by the consumer. The demand for the locally produced rice is high, however due to it unavailability in sufficient quantities throughout the year, makes consumers patronize the imported brands the more (Bam *et al.*, 1998). Rice consumers in Ghana attributed their preference for imported rice to locally produced rice mostly because of the impurities (stones and other foreign materials) it contains and the unavailability of it in sufficient quantities all year round (Diako *et al.*, 2010). Most of respondents from the survey expressed their knowledge on quality and standards of rice in terms of Purity, Aroma, Colour, Flavour, Texture and Swelling capacity of the rice.

Aroma recorded the highest followed by Purity in measuring rice quality by consumers. During the survey, it was observed that the demand for the locally produced rice is high, however due to it unavailability in sufficient quantities throughout the year makes consumers rely more on the imported brands.

Some quality issues or perceptions about local rice in the Ghanaian markets were cleared and others confirmed by respondents as factors preventing the patronage of these local rice varieties (Table 4.4). Admixtures and impurities were confirmed to be prevalent in most locally produced and milled rice even though the mass majority agreed that it is very tasty and palatable with moderate price. Consumers strongly disagreed with the perception that local milled rice has unpleasant odour but rather revealed that there are currently a lot of aromatic or perfumed rice being produced locally to meet consumer's preference. However, due to the sub-standard rice milling equipment, the locally milled rice cannot be compared with its foreign counterparts in terms of milling quality. Stickiness of the local rice compared to the imported brands was attributed to the high starch content of the local rice varieties.

5.1.5 Harvesting and Post-harvest Handling

Rice quality is significantly affected by the time and method of harvesting. This could be due to the fact that the moisture content of the rice at the time of harvesting is very essential so as the tools or equipment used in harvesting (manually with sickle or mechanically with the use of a combine harvester). Late harvesting can cause shattering of grains and also cracking during threshing or with the use of combine harvesters. The majority of farmers especially in the northern region harvest their rice below the recommended moisture content (20% - 25%) for harvesting hence resulting in high breakages during milling thereby affecting the rice quality.

Threshing of rice paddy after harvest also affects quality in terms of grain cracking or breakage and the introduction of foreign materials into the threshed paddy depending on the method used.

Paddy rice threshed on bare floors always contains stones, sand and other unwholesome materials while the use of tarpaulins, threshing (bambam) boxes or mechanized rice threshers reduces the presence of foreign materials in the paddy hence the milled rice. With the increasing sensitization and training of rice farmers by various stakeholders such as foreign donor agencies sponsored programs in Northern Ghana, the adoption of the use of tarpaulins in manual rice threshing is really gaining grounds in helping solve the challenge of the presence of stones in locally produced and milled rice.

5.2 FUNCTIONAL PROPERTIES

5.2.1 Bulk Density

Bulk density is dependent upon the grain size of the rice varieties and can also be described as the measure of weight of the rice flour. It is influenced by the structure of the starch polymers and a loose structure of the starch polymers could result in low bulk density (Juliano, 1993).

There were no significant differences in between the rice varieties in terms of bulk density where the mean ranged from 0.87g/ml to 1.00g/ml indicating high bulk densities for all the varieties with Togo marshall recording the highest. The high bulk densities of flours suggest their suitability for use in food preparations and in contrast, low bulk density would be an advantage in the preparation of complementary foods (Akpata and Akubor, 1999)

In agreement with the above statement, Akubor and Obieguna (1999) reported that bulk density of a sample could be used to determine the packaging requirements, handling of material and application in wet processing, in the food industry, as it relates to the load the sample could carry if allowed to rest directly on each other. The variety and storage did not have any significant effect on the relative bulk density of the rice flour samples.

5.2.2 Foaming Capacity

Foaming capacity is assumed to be dependent on the configuration of protein molecules. Flexible proteins have good foaming capacity but highly ordered globular molecule gives low foam ability (Graham *et al.*, 1976). The Foaming capacities of the rice varieties showed significantly differences in their mean values and also in their interactions during storage.

Sikamo variety recorded the highest foaming capacity and the least was Texas rice (Table 4.6). The bakery industries required food ingredients that have good foaming capacity and stability for use in baking (Akubor *et al.,* 2000).

5.2.3 Oil Absorption Capacity

The oil absorption capacity of food is important as oil acts as a flavour retainer and improves the mouth feel of foods (Abulude *et al.,* 2006). The water and oil binding capacity of food protein is dependent on the intrinsic factors like amino acid composition, protein conformation and surface polarity or hydrophobicity. Togo marshall which is a locally produced rice variety recorded the highest Oil Absorption Capacity (OAC) of all the other rice varieties, followed by Mandi, Gbewaa and Royal feast varieties which were not significantly different from each other but were significantly different from the Togo marshall. The OAC of rice seems to decrease with storage or aging of the rice as shown in Table 4.7 from the study.

5.2.4 Water Absorption Capacity

Water absorption capacity (WAC) is the ability of a product to relate with water under conditions where water is limiting (Singh, 2001). Niba *et al*., (2001) described water absorption capacity as an essential processing factor that has implications for viscosity. Additionally, water absorption capacity is significant in bulking and the consistency of products as well as baking applications and it is an essential functional property required in food formulations especially those involving dough handling such as "Omo-tuo" (rice balls).

The Water Absorption Capacity was observed highest in Red rice flour (134.00ml/g), followed by Togo marshall (90.67ml/g) and Royal Feast (80.50ml/g) while the least was observed in AGRA rice variety. The highest WAC of the Red rice flour could be attributed to the presence of higher amount of fibre and carbohydrates (starch) in its flour. This could also be attributed to the lose structure of starch polymers while low WAC value indicates the compactness of the structure (Adebowale *et al.,* 2005).

Water absorption capacity of flour is a useful indicator of whether protein can be integrated with the aqueous food formulations, especially, those involving dough handing. Interactions of protein with water, is essential to attributes such as hydration, swelling power solubility and gelation.

5.2.5 Swelling Capacity

Swelling capacity defines the degree to which a flour sample increases in volume when soaked in water in relation to its initial volume and it is dependent on the particle size, variety and the processing methods or unit operations, Moorthy and Ramanujam (1986). The flour of parboiled rice has been reported to have a higher swelling capacity as compared to non-parboiled raw rice (Suresh *et al.,* 2015).

There were no significant differences among the three rice samples; Sikamo, Red rice and Royal feast rice which were observed to have high Swelling capacities of 6.56g/ml, 6.39g/ml and 6.336g/ml respectively with the highest recorded by Sikamo variety. Moorthy and Ramanujam (1986) also reported that the swelling ability of flour granules is an indication of the level of associative forces within the granule, while Loos *et al.,* (1981) also related swelling power to the water absorption index of the starch based flour during heating.

The eating quality of food is often associated with the retention of water in the swollen starch granules (Rickard *et al* 1992). The Mandi rice sample was observed to record the least mean value of 5.19g/ml in swelling capacity and hence was significantly different from the other varieties. Swelling ability of food flour is often connected to their protein and starch contents. Protein content higher in flour may cause the starch granules to be embedded within a stiff protein matrix, which subsequently limits access of the starch to water and restricts its swelling capacity. Flours with lower protein and higher starch content just as recorded by Sikamo in the study (Table 4.13 & 4.14) have a higher swelling ability (Table 4.9). In addition to protein content, a higher concentration of phosphorous may increase hydration and swelling ability by weakening the level of bonding within the crystalline domain (Aprianita *et al.,* 2009).

5.3 SENSORY PROPERTIES

5.3.1 Aroma

Aromatic rice is sold at a higher price (premium) in most local markets. From the study, the Gbewaa variety which is a locally produced variety was the most preferred in terms of aroma. From the result it recorded the highest mean value of 4.22 followed closely by Royal feast which is an imported brand. Red rice was adjudged as the variety with the least or no aroma by the panelist. Environmental conditions can cause a lot of the variation seen in aroma as can be observed from Table 4.10, where the aroma seems to be affected by storage of the rice samples.

A comparative study of the volatile substances of aromatic and non-aromatic rice varieties indicated that 2-acetyl-1-pyrroline (2AP), which contributed to particular flavour in aromatic rice and has relatively lower odour threshold among rice volatiles, occurs at higher levels in aromatic rice varieties and at significantly lower levels in non-aromatic rice varieties (Buttery *et al.,* 1983). It could be assumed that, this “pop-corn” or “roasted” flavour aroma observed in the Gbewaa, Royal feast and AGRA rice varieties might be as a result of the presence of the 2AP compound in the varieties.

5.3.2 Taste

Locally produced Gbewaa and imported Royal feast rice varieties were the most preferred rice varieties compared to the others in terms of taste. However, in terms of scoring, Gbewaa recorded the highest rate of preference with a mean value of 4.30 to that of Royal feast. Mandi, a non-aromatic locally produced variety recorded the least in taste preference by the panelist. It could assumed that the volatile 2AP compound which is found in aromatic rice, giving it a striking flavour, contributed to the acceptable taste of both the Gbewaa and Royal feast rice varieties/brand (Buttery *et al.*, 1983) because it was observed that preference for taste of the rice samples seemed to decrease with storage duration just as in the case of the aroma (Table 4.10). However, taste could also be influenced by the amount of starch content in the rice variety/brand after cooking, which may either give an "off taste" or make it tasty depending on its amylose or amylopectin level (Juliana, B.O. 1993).

5.3.3 Colour

One of the most essential characteristics of raw and cooked rice is its degree of whiteness(Goodwin *et al*. 1992, Suwansri *et al.* 2002).There were significant differences ($p<0.05$) in terms of colour preference among the rice varieties. Royal feast, Texas rice and Gbewaa varietieswere the most preferred but were not significantly different from each other according to the result. Royal feast rice recorded the highest score of 4.53, followed by Texas rice (4.48) and this might be attributed to the milling quality or the use of an advance world standard milling equipment with polishers in the developed country where the rice brands were imported from as compared to the low grade one-pass milling equipment found in Ghana used to mill the Gbewaa rice. However, the Gbewaa and AGRA varieties which were the third and fourth most preferred varieties in term of colour competed squarely with the imported brands and if given equal opportunity with the same advance milling equipment as the imported brands might have been the most preferred.

Red rice recorded the least preferred which can be attributed to its unique peculiar reddish brown coloration. Consumers frequently glanced at a rice sample in the markets and make a decision based largely on the physical appearance including colour. Degree of whiteness is often used as a representative description of colour.

5.3.4 Flavour

Flavor is one key factor that accounts for consumer acceptance and constant purchase of rice and it is the most recognizable feature to define foods as it is a comprehensive stimulation of taste and odour receptors (Limpawattana and Maruj, 2007). Basic tastes are detected by gustatory receptors within the mouth where aroma is then combined to make up all flavors. Theoretically, the human nose has an odour detection limit of about 10^{-19} moles (Mistry *et al.*, 1997) making it a sensitive tool for the detection of potent volatiles. Results from the study indicates that there were no significant difference ($p<0.05$) between Royal feast and Gbewaa rice varieties in terms of flavour as perceived by the sensory evaluation panels. The most preferred variety in flavour was Royal feast with a mean score of 4.05, followed by Gbewaa rice with 3.95 while Red rice maintained its least preference as in the Aroma analysis compared to the other varieties/brands.

Rice flavour is a significant factor in determining quality and consumer acceptability as exemplified by aromatic rice which is highly favoured and commands a high market price. To most people rice is a rather bland food and minor changes in sensory properties, especially aroma, can make rice and rice products unacceptable to consumers.

5.3.5 Texture

Rice texture has been revealed to lead the approval of rice by consumers when eaten as whole grain. Texture has been defined as a multidimensional property that only humans can perceive, define and quantify. It describes what a person might experience in his/her mouths when ingesting the food/rice such as initial mouthfeel, hardness, adhesiveness, resilience and gumminess (Zhou Z. *et al.*, 2001)

The two most preferred rice varieties in terms of texture from the study were Gbewaa (local rice) and Royal feast (imported rice) and both were not statistically different ($p>0.05$) from each other but were significantly different ($p<0.05$) from the other rice samples. As shown in Table 4.14, locally produced Gbewaa rice scored the highest rating in terms of preference, followed by Royal feast; an imported brand. AGRA rice and Togo marshall followed as the third and fourth most preferred ahead of Texas rice. Locally produced Red rice sample was adjudged the least preferred rice variety in terms of textural quality.

Rice texture is affected by the amylose content, variety, storage time and the cooking method. For example, boiled rice with low amylose content is soft and sticky while those high in amylose are firm and fluffy (Lyon *et al.,* 1999) and the texture of cooked rice, stored over the storage period was harder and less sticky than cooked freshly harvested rice.

5.3.6 Hardness

Results from the sensory evaluation carried out during the study indicate that the Panelist preferred the locally produced Gbewaa rice variety the most to the other rice samples. Royal feast, Texas rice and Togo marshall followed in that order but these three varieties were not significantly different ($p>0.05$) from each other but they however showed significant differences ($p<0.0$) from the Gbewaa and the other rice samples. From Table 4.15, it can be observed that hardness is affected by storage of grains as the panelist scoring preference for quality in terms of grain hardness decreases in value as the storage period increased. This implies that the cooked rice becomes harder during storage compared to when they were freshly harvested. High amylose level in the rice renders the rice grains hard when cooked and hence less preferred to tender and softer varieties by consumers (Lyon *et al.,* 1999).

5.3.7 Stickiness

Stickiness is the tendency of the cooked rice to adhere to itself and to other objects (Fellers *et al.,* 1983). There were no significant differences ($p>0.05$) in the mean values of all the rice samples for stickiness except for the Red rice which recorded the least score in consumer preference level. However, significant differences ($p<0.05$) were observed in the interaction between the rice sample/varieties and the various storage periods. Table 4.16 shows that stickiness decreases as the rice is stored for a longer period. Royal feast, Gbewaa, AGRA and Togo marshall were highly preferred in terms of their sticky characteristics.

Studies show that the stickiness of cooked rice is linked to the quantity of sugar in the surface layer of the boiled rice extracts and these extracts also contained a lower quantity of amylose fraction and larger quantity of short-chain amylopectin fraction (Fellers *et al.*, 1983). These components are once removed from the rice during boiling and finally absorbed into the surface layer, thus giving the rice its sticky characteristics.

5.3.8 Loose particles

Results from the study indicated that there were no significant differences ($p>0.05$) in terms of loose rice particles between the rice varieties/brands. Their mean score values ranged from 3.27 to 3.87. Roya feast recorded the highest mean value of 3.87, followed by Texas rice with 3.85 while Togo marshall recorded the least in preference with a mean value of 3.27. The looseness in the cooked rice particles of Royal feast and Texas rice could be attributed to the variety or age of the rice.

During storage, retrogradation of the starch led to an increase in hardness as well as a decrease in the adhesion or stickiness of the cooked rice particles (Sobolewska-Zielińska J., Fortuna T., 2010). Generally, as the rate of starch retrogradation increased during storage, rice hardness increased and stickiness decreased therefore freshly harvested rice (in the case of the locally produced varieties) were high in starch content hence making them more sticky compared to the imported rice samples/brands which had loose particles when cooked.

5.4 PROXIMATE ANALYSIS

5.4.1 Moisture

Moisture represents the amount of the water content of the flour samples and its total solid content. It is also an index of storability; hence a lower moisture content of food sample suggests better shelf life and stability (Eke-Ejiofor J., Nwiganale L., 2016).

The percentage moisture content of the sample rice varieties ranged between 3.83% - 6.33% before the rice samples were stored under same environmental conditions for a period of four months. Mandi, one of the locally produced non-aromatic varieties recorded the lowest moisture content, this indicate that the Mandi sample could store longer compared to the others when placed under the same storage conditions because of the low moisture content. The results corroborates with the findings of Abulude and Ojediran (2006), on raw and processed rice. The low moisture content might be attributed to the high dehydrating temperature in the Northern region where the rice samples where produced, milled and stored.

After the four months storage of the eight identified rice samples, significant differences ($p<0.01$) were observed between the samples in terms of moisture content. The percentage moisture contents now ranged between 4.50% - 6.83% with Royal feast maintained as the sample with the highest moisture content while the Gbewaa variety recorded the least in moisture content. However, the marginal increase in percentage moisture content of almost all the stored rice samples might be due to the absorption of moisture from the storage environment as humidity was high during the final month of storage in the region.

5.4.2 Ash

The mineral elements found in food samples are measured by the amount of ash content in the food. Ash is one of the constituents in the proximate analysis of biological materials in analytical food chemistry, it consist essentially of non-organic, carbonates and bicarbonates and metals. It is the term given to all compounds that are not considered organic or water. It includes metal salts, which are vital for processes that require ions such as Sodium (Na^{+}), Potassium (K^{+}), Calcium (Ca^{2+}). Trace minerals, which are required for unique molecules, such as chlorophyll and haemoglobin are also included (Osagie, 1992).

There were no significant differences ($p<0.01$) in Ash content between the eight samples rice varieties both before and after four months of storage. The ash contents observed before storage were higher than the reported values of 0.30% - 0.80% for milled rice by Juliano, 1985b.Red rice was observed to have highest value of 1.33% in ash content before storage. The higher ash content observed in the flours could be attributed to the minimal polishing of the rice grains during milling by the use of the one-pass hullers because minerals (ash) are more concentrated in the outer layers of brown rice or in the bran fraction. However, the ash content of the samples reduced after storage and their percentage values ranged between 0.09% - 0.43% which indicates that storage have an effect on the ash content of rice.

Gbewaa variety recorded the highest in ash content (0.43%) followed by Red rice (0.36%) at the end of storage while Mandi recorded the least percentage of 0.09% in ash. The ash content is an indication of minerals present in the rice flour and the result indicated that there were no significant differences ($p<0.01$) in the ash content between all the rice varieties which could be sources of mineral elements with nutritional importance such as iron, which is very essential for blood formation.

5.4.3. Protein

Proteins perform a variation of indispensable functions in mammalian organisms. Dynamic uses include catalysis of chemical changes, transport metabolic control and contraction. Proteins provide the matrix for bone and connective tissue in their structural functions, giving structure and form to the human organism (Juliana, B.O. 1993).

The protein content of samples before storage ranged between 7.68% - 9.87% which were higher than the reported values of 6.30% - 7.10% for milled rice by Juliano, (1985b) but comparable to the range of 6.30% - 9.50% as recorded by Derycke, *et al* (2005) and these differences observed might be due to the variety and processing methods. The amount of fats, minerals, and proteins are greater in the germ and outer layers of rice than in the starch endosperm (Juliano, 1985b) and for this reason, the minimal polishing of the locally produced and processed rice might be a contributing factor for the high protein content. AGRA rice was observed to have the highest protein content followed by Texas rice while the least in protein content before storage was recorded by the Sikamo variety.

Significant difference ($p<0.01$) were observed in the protein content of all the sample rice varieties after storage with mean percentage values ranging from 6.04% - 10.63%. Togo marshall, however, was the only variety with an increment in protein content from 8.85% to 10.63% and was eventually recorded as the highest. This could be attributed to environmental factors or the high level of free amino acids which increases during storage of milled rice (Zhou Z. *et al.*, 2001). Texas rice, Royal feast, Sikamo, Mandi, Gbewaa and AGRA rice varieties however, showed no significant variations in their protein contents (Table 4.18) but were significantly different from Red rice which recorded the least in protein (6.04%) at the end of storage.

5.4.4. Crude Fat

Fat serves as a source of calories and are required to prevent or correct essential fatty acid deficiency (Abida *et al*., 2001).The fat values observed for the rice samples before storage were not significantly different ($p>0.01$) between the varieties with a range of 1.17% - 2.91%. Mandi recorded the highest fat content followed by Texas rice, Red rice and Sikamo as the fourth highest (Table 4.19) while the variety with the least crude fat content was observed to be AGRA rice. The high fat content of the samples could be attributed to the processing method since minerals, fats, and proteins are much higher in the germ and outer layers of rice grain than in the starch endosperm (Juliano, 1985b).

There were significant differences observed between the eight rice varieties in terms of crude fat content at the end of storage. Percentage mean value ranged from 0.50% to 2.67% with locally produced Togo marshall and AGRA rice varieties recording the highest, followed by Red rice while the least recorded in crude fat was by the Gbewaa variety. The relatively higher crude fat content observed in the samples suggest that the rice flours could be good flavour retainers because of their higher fat content which might suggest the palatable taste of rice and could contain the fat soluble vitamins A, D, E and K (Abida *et al*., 2001).

5.4.5 Crude Fibre

Crude fibre is a measure of the amount of indigestible roughage/cellulose, lignin, pentosans and other components of this type in food substances. These components have little food value but are very necessary for proper peristaltic action in the intestinal tract of mammals or it is a type of carbohydrate that helps keep our digestive systems healthy (Juliano, 1993).

There were no significant differences ($p>0.01$) between all the rice varieties in terms of their crude fibre content. The mean values observed for the rice samples before storage ranged from 1.27% to 2.91% in fibre contents.

Significant differences ($p<0.01$) in fibre contents were observed between the varieties/brand after storage with a mean ranged from 0.53% to 2.57%. Red rice had the highest crude fibre content of 2.57%, followed by Texas rice with a value of 2.22% and the varieties with the lowest fibre contents were recorded by Mandi and AGRA rice (Table 4.19). The reduction in fibre contents as observed in this study might be as a result of some biochemical changes during storage. Fibre provides a variety of health benefits and is very important in reducing the risk of chronic disease such as obesity, diabetes, cardiovascular disease and diverticulitis or bowel cancer (Zhou K. *et al.,* 2004).

5.4.6 Carbohydrate

There were no significant differences ($p>0.01$) observed between both the locally produced and imported rice varieties in terms of their carbohydrate contents before storage. However, the carbohydrate contents of the samples ranged from 78.61% to 82.19% which fell within the range of 77% - 89% as recorded by Juliano, (1985b).Rice contains complex carbohydrates which serve as fuel from which the human body derives most of its energy.

Carbohydrates in diets are very vital for satisfying the body's energy requirements. Consuming diets low carbohydrate will gradually result in an increase in sluggishness which will eventually lead to an increase in weight after an initial weight loss. This initial loss of weight is often just the reduction of fluids in the cells, or water weight. This loss of fluids is not always healthy. Although the actual amount of carbohydrate requirement differs from individual to individual, the total daily calories of carbohydrate consumption should be in the range of 45% to 60% in a given day (Harden, 2009).

Mandi rice variety recorded the highest in carbohydrate content (85.38%), followed by Gbewaa (85.23%), Sikamo (84.18%) and AGRA rice (83.86%) while Togo marshall was observed to record the lowest in carbohydrate at the end of the four months storage period. Significant differences ($p<0.01$) occurred between the varieties/brands, however, there were no statistical variance between the Mandi and Gbewaa varieties, same as that of Sikamo and AGRA rice.
Several of the physiochemical and functional changes which occurred during the storage, such as swelling, stickiness, water absorption were all caused by protein starch interactions, other changes due to ageing are not yet fully understood (Radhika, 1993).

5.5 SUSCEPTIBILITY TO INSECT INFESTATION

The rate of insect infestation is an essential quality factor of food grains and it is a major unending problem for the grain and milling industries. Insects can cause serious economic losses in rice because of their ability to infest paddy, milled rice and the by-products of milling material that accumulates in structures and equipment where rice is processed. Rice weevils (*Sitophilus oryzae*) are freely moving insects and may be found anywhere within the grain mass (Gentry *et al.* 1991] and capable of infesting all kinds of rice products.

During the study, no insect pest was identified or seen in any of the eight rice samples after the first month of storage (30 days), however, Texas rice was the first to record a total of eight (8) rice weevils present in the stored sample at the end of the second month of storage (60 days). With Texas rice being one of the two imported brands/varieties used for the study, the infestation could be due to the age of the rice since it cannot be ascertain the exact age of the Texas rice variety before it was purchased for this study or even imported into the country. This is because imported rice is believed to originate from a more improved grain postharvest system with comparative improved processing, handling and storage facilities than the locally produced rice. Such improved mills are often run alongside huge silos or pack houses where the usage of pesticidal fumigants to control storage pests is a common practice.

The number of rice varieties infested with insects at the end of the third month of storage (90 days) increased to three with two of them being locally produced varieties. Texas rice recorded insect population of 28 adult weevils and larvae, followed by Togo marshall harbouring 15 and Mandi with 12 rice weevils. Studies shows that the rice weevil can cause grains infestation even in the field (Cho, *et al.* 1998). Hence it could be assumed that the locally produced rice varieties might have been infested in the field with the weevils either before or during the time of harvest, probably due to the poor harvesting and handling practices. Several studies have also revealed that, milling operations (especially polishing) have an effects on milled rice susceptibility to the rice weevil (Beckett, *et al.* 1994). A properly and well-polished milled rice is less susceptible to weevils infestation (McGaughey, 1974).

Sikamo kept clean storage for four months before showing signs of weevil's infestation. 3 rice weevils were identified in the Sikamo samples after 120 days of storage, Mandi recorded 2 rice weevils, Togo marshall 43 and 44 adults and larvae (dead and alive) recorded in Texas rice.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

This study identified six (6) most patronized or commercial locally produced rice varieties in Ghana and two (2) most preferred imported rice brands/varieties on the Ghanaian markets. The identified rice were of aromatic and non-aromatic varieties. Gbewaa, Mandi, Sikamo, Togo marshall, Red rice and AGRA rice were the local varieties identified while the imported brands/varieties selected were Royal feast and Texas rice. The imported varieties were mostly preferred by consumers because of it purity quality and aromatic flavour. However, the study revealed that there were equally very tasty aromatic varieties produced locally in Ghana such as the Gbewaa rice which can be compared with the imported Royally feast brand in taste, aroma, flavour and essential food nutrients. Colour and purity of the local varieties can be improved with the use of state of the art milling equipment.

The locally produced varieties were observed to have high protein and carbohydrate contents compared to their imported counterparts. The crude fibre, crude fat, and ash contents of the local varieties were more prominent than the imported brands/varieties due to the presence of bran on the local milled rice grains as a result of the unpolished grains.

Royal feast and Texas rice were the most preferred in terms of their loose grain particles or low sticky properties as matched with the local varieties which were observed to be high in starch therefore rendering them more suitable for most of the local Ghanaian dishes such as “Omotuo” (rice balls), waakye, porridge (rice water) and weaning meals for infants.

The high water absorption capacity observed in Red rice and Togo marshall suggest that they could be valuable functional ingredients in baking as well as food formulations. Foams are used to improve texture, consistency and food appearance hence the local varieties that recorded good foaming capacities can be used as ingredients in bakery products as reported by Akubor *et al.*, (2000). Comparatively, the locally produced rice varieties recorded the best results or higher mean values in the proximate and functional analysis and majority of the sensory parameters studied. However, they were more susceptible to storage insects/pests (rice weevils) which might be as a result of poor handling and processing.

Nutrient contents and functional properties of the milled rice samples decreased during the storage at ambient temperature (28-30^{0}C) for a period of four months.

6.2 RECOMMENDATIONS

1. Further studies should be carried out to determine the shelf life and microbial (fungal) infection of the six locally produced rice varieties identified from this study.

2. Rice processors should be encouraged to grade milled rice so as to promote the quality compared with imported brands and enlightenment programs set up particularly in the urban areas to encourage the consumption of local rice, emphasizing on its nutritional qualities.

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APPENDICES

APPENDIX 1: FREQUENCY TABLES FOR FIELD SURVEY

1a: Sex/Gender of Respondents

Gender	Frequency	Percent	Cumulative Percent
Male	118	59.0	59.0
Female	82	41.0	100.0
Total	200	100.0	

1b: Gender of Respondents by categories

	Male	Female
Consumer	26.0%	24.0%
Farmer	28.5%	6.5%
Processor	3.0%	2.0%
Trader	1.0%	6.5%
Aggregator	0.5%	2.0%
Total	59%	41%

1c: Categories of respondents

	Frequency	Percent	Cumulative Percent

Consumer	100	50.0	53.0
Farmer	70	35.0	87.0
Processor	10	5.0	92.5
Trader	15	7.5	99.0
Aggregator	5	2.5	100.0
Total	200	100.0	

1d: Educational level of respondents

	Frequency	**Percent**	**Cumulative Percent**
No education	63	31.5	31.5
Primary	31	15.5	47.0
MSLC/JSS	49	24.5	71.5
Secondary/Technical School	23	11.5	83.0
Tertiary	34	17.0	100.0
Total	200	100	

1e: Preference of milled rice in the Ghanaian market

	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Local rice	135	67.5	68.5	68.5
Imported rice	62	31.0	31.5	100.0
Sub Total	197	98.5	100.0	
N/R	3	1.5		
Sub Total	3	1.5		
Total	200	100.0		

1f: Moisture content at which harvesting is usually done

	Moisture content	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	12%	17	8.5	26.2	26.2
	14%	20	10.0	30.8	56.9
	16%	11	5.5	16.9	73.8
	Very dry and shattering (<12%)	17	8.5	26.2	100.0
	Total	65	32.5	100.0	
Missing	N/A	135	67.5		
	Total	135	67.5		
Total		200	100.0		

1g: Identified locally produced rice varieties

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Gbewaa	108	54.0	61.4	61.4
	Mandi	14	7.0	8.0	69.3
	Togo marshall	25	12.5	14.2	83.5
	Red rice	12	6.0	6.8	90.3
	AGRA rice	6	3.0	3.4	93.8
	Sikamo	11	5.5	6.3	100.0
	Total	176	88.0	100.0	
Missing	N/A	20	10.0		
	N/R	4	2.0		
	Total	24	12.0		
Total		200	100.0		

1h: Rice preference per region

Region	Percentage of rice preferred	
	Local rice (%)	Imported rice (%)
Ashanti Region	67.30	32.70
Greater Accra Region	20.00	80.00
Northern Region	93.90	6.10

1i: Reasons for local rice preference

	Reasons	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Tasty and Palatable	94	47.0	56.3	56.3
	Readily Available	31	15.5	18.6	74.9
	Energy giving and Starchy	9	4.5	5.4	80.2
	Nutritious	18	9.0	10.8	91.0
	Soft when cooked	4	2.0	2.4	93.4
	High swelling capacity	8	4.0	4.8	98.2
	Preparation of special dishes	3	1.5	1.8	100.0
	Total	167	83.5	100.0	
Missing	N/A	20	10.0		
	N/R	13	6.5		
	Total	33	16.5		
Total		200	100.0		

1j: Methods of threshing rice locally

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	On bare floor	25	12.5	36.8	36.8
	On tarpaulin	36	18.0	52.9	89.7
	In threshing boxes	2	1.0	2.9	92.6
	Use of mechanized thresher	5	2.5	7.4	100.0
	Total	68	34.0	100.0	
Missing	N/A	132	66.0		
	Total	132	66.0		
Total		200	100.0		

1k: Reasons for imported rice preference

	Reason	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Tasty and Palatable	57	28.5	30.0	30.0
	Readily Available	27	13.5	14.2	44.2
	Aromatic	3	1.5	1.6	45.8
	Clean, well-Polished and No stones	33	16.5	17.4	63.2
	Healthy and Nutritious	30	15.0	15.8	78.9
	Long grain, loose particles / less starchy	27	13.5	14.2	93.2
	Easy to cook and High swelling capacity	7	3.5	3.7	96.8
	Attractive packaging	6	3.0	3.2	100.0
	Total	190	95.0	100.0	
Missing	N/A	1	0.5		
	N/R	9	4.5		
	Total	10	5.0		
Total		200	100.0		

APPENDIX 2: ANALYSIS OF VARIANCE TABLES

2a. Functional Properties

 Analysis of Variance Table for Bulk density

Source	DF	SS	MS	F	P
REP	2	0.00978	0.00489		
MONTH	3	0.04906	0.01635	0.30	0.8236
VAR	7	0.12921	0.01846	0.34	0.9318
MONTH*VAR	21	0.03323	0.00158	0.03	1.0000
Error	62	3.35362	0.05409		
Total	95	3.57490			
Grand Mean 0.9601	CV 24.22				

 Analysis of Variance Table for Foaming Capacity

Source	DF	SS	MS	F	P
REP.	2	0.01	0.006		
MONTH	3	547.42	182.473	726.93	0.0000
VAR	7	99.84	14.263	56.82	0.0000
MONTH*VAR	21	409.93	19.520	77.76	0.0000
Error	62	15.56	0.251		

Total	95	1072.76
Grand Mean 3.1203	CV 16.06	

 Analysis of Variance Table for Oil Absorption Capacity

Source	**DF**	**SS**	**MS**	**F**	**P**
REP	2	100.0	50.00		
MONTH	3	3099.0	1033.00	23.46	0.0000
VAR	7	3858.0	551.14	12.52	0.0000
MONTH*VAR	21	13707.0	652.71	14.82	0.0000
Error	62	2730.0	44.03		
Total	95	23494.0			
Grand Mean 77.500	CV 8.56				

				F	P
					0.0000

Analysis of Variance Table for Water Absorption Capacity

Source	DF	SS	MS		
REP.	2	18.1	9.04		
MONTH	3	8408.5	2802.83	70.51	
VAR.	7	34279.2	4897.02	123.19	0.0000
MONTH*VAR.	21	23901.5	1138.17	28.63	0.0000
Error	62	2464.6	39.75		
Total	95	69071.8			
Grand Mean 85.708	CV 7.36				

 Analysis of Variance Table for Swelling Capacity

Source	DF	SS	MS	F	P
REP.	2	0.0127	0.00633		
MONTH	3	2.6217	0.87391	1.59	0.2012
VAR	7	19.1260	2.73229	4.97	0.0002
MONTH*VAR	21	27.2330	1.29681	2.36	0.0048
Error	62	34.1091	0.55015		
Total	95	83.1026			
Grand Mean 5.9366	CV 12.49				

2b. Sensory Properties

 Analysis of Variance Table for Aroma

Source	DF	SS	MS	F	P
Rep.	14	34.262	2.4473		
Var.	7	85.815	12.2592	9.23	0.0000
Month	3	7.106	2.3688	1.78	0.1497
Var.*Month	21	41.877	1.9941	1.50	0.0723
Error	434	576.671	1.3287		
Total	479	745.731			

				F	P
					0.0000

Grand Mean 3.6313 CV 31.74

Analysis of Variance Table for Taste

Source	**DF**	**SS**	**MS**		
Rep.	14	46.867	3.3476		
Var.	7	77.965	11.1378	8.33	
Month	3	33.756	11.2521	8.42	0.0000
Var.*Month	21	59.994	2.8568	2.14	0.0026
Error	434	580.067	1.3366		
Total	479	798.648			

Grand Mean 3.6396 CV 31.76

- Analysis of Variance Table for Colour

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep.	14	52.050	3.7179		
Var.	7	126.881	18.1259	16.56	0.0000
Month	3	13.423	4.4743	4.09	0.0070
Var.*Month	21	46.460	2.2124	2.02	0.0050
Error	434	475.017	1.0945		
Total	479	713.831			

Grand Mean 3.9188 CV 26.70

- Analysis of Variance Table for Flavour

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep.	14	41.592	2.9708		

				F	P
					0.0000
Var.	7	82.025	11.7179	7.56	0.0000
Month	3	2.175	0.7250	0.47	0.7049
Var.*Month	21	33.258	1.5837	1.02	0.4346
Error	434	672.542	1.5496		
Total	479	831.592			
Grand Mean 3.4708	CV 35.87				

Analysis of Variance Table for Texture

Source	**DF**	**SS**	**MS**		
Rep.	14	42.217	3.01548		
Var.	7	58.548	8.36399	5.66	
Month	3	9.606	3.20208	2.17	0.0914
Var.*Month	21	27.977	1.33224	0.90	0.5900
Error	434	641.650	1.47846		
Total	479	779.998			
Grand Mean 3.5021	CV 34.72				

 Analysis of Variance Table for Hardness

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep.	14	43.367	3.0976		
Var.	7	43.315	6.1878	3.75	0.0006
Month	3	30.006	10.0021	6.06	0.0005
Var.*Month	21	44.310	2.1100	1.28	0.1847

-

				F	P
					0.0000
Error	434	716.900	1.6518		
Total	479	877.898			

Grand Mean 3.4854 CV 36.87

- Analysis of Variance Table for Stickiness

Source	DF	SS	MS	F	P
Rep.	14	73.904	5.27887		
Var.	7	57.815	8.25923	4.94	0.0000
Month	3	15.973	5.32431	3.18	0.0238
Var.*Month	21	36.077	1.71796	1.03	0.4289
Error	434	726.229	1.67334		
Total	479	909.998			

Grand Mean 3.5646 CV 36.29

Analysis of Variance Table for Loose particles

Source	DF	SS	MS	F	P
Rep.	14	51.792	3.6994		
Var.	7	21.492	3.0702	1.80	0.0864
Month	3	35.892	11.9639	7.00	0.0001
Var.*Month	21	54.542	2.5972	1.52	0.0665
Error	434	742.075	1.7099		
Total	479	905.792			
Grand Mean 3.5208	CV 37.14				

2c. Proximate Analysis

❖ **Before storage**

Analysis of Variance Table for moisture

Source	DF	SS	MS	F	P
Varieties	7	15.5000	2.21429	2.10	0.1032
Error	16	16.8333	1.05208		
Total	23	32.3333			
Grand Mean 5.3333	CV 19.23				

Analysis of Variance Table for ash

Source	DF	SS	MS	F	P
Varieties	7	0.95833	0.13690	1.10	0.4113
Error	16	2.00000	0.12500		
Total	23	2.95833			
Grand Mean 0.9583	CV 36.89				

Analysis of Variance Table for protein

Source	DF	SS	MS	F	P
Varieties	7	9.8307	1.40439	8.10	0.0003

Error	16	2.7755	0.17347		
Total	23	12.6062			
Grand Mean 8.9050	CV 4.68				

Analysis of Variance Table for fat

Source	DF	SS	MS	F	P
Varieties	7	6.5497	0.93567	0.65	0.7069
Error	16	22.9025	1.43141		
Total	23	29.4522			
Grand Mean 1.8754	CV 63.79				

Analysis of Variance Table for fibre

Source	DF	SS	MS	F	P
Varieties	7	8.8478	1.26397	1.23	0.3424
Error	16	16.4238	1.02649		
Total	23	25.2716			
Grand Mean 2.0579	CV 49.23				

Analysis of Variance Table for carbohydrate

Source	DF	SS	MS	F	P
Varieties	7	29.508	4.21546	0.92	0.5143
Error	16	73.023	4.56396		
Total	23	102.532			
Grand Mean 80.870	CV 2.64				

❖ **After storage**

Analysis of Variance Table for moisture

Source	DF	SS	MS	F	P
Varieties	7	11.6250	1.66071	6.90	0.0007
Error	16	3.8533	0.24083		
Total	23	15.4783			
Grand Mean 5.5417	CV 8.86				

- Analysis of Variance Table for Ash

Source	DF	SS	MS	F	P
Varieties	7	0.30753	0.04393	2.05	0.1109
Error	16	0.34267	0.02142		
Total	23	0.65020			
Grand Mean 0.2579	CV 56.74				

- Analysis of Variance Table for Protein

Source	DF	SS	MS	F	P
Varieties	7	42.4475	6.06392	1.89	0.1381
Error	16	51.3313	3.20821		
Total	23	93.7788			
Grand Mean 8.0754	CV 22.18				

- Analysis of Variance Table for Fat

Source	DF	SS	MS	F	P
Varieties	7	13.9896	1.99851	31.20	0.0000
Error	16	1.0250	0.06406		
Total	23	15.0146			
Grand Mean 1.7292	CV 14.64				

- Analysis of Variance Table for Fibre

Source	DF	SS	MS	F	P
Varieties	7	15.6288	2.23268	75.14	0.0000
Error	16	0.4754	0.02971		
Total	23	16.1042			
Grand Mean 1.3508	CV 12.76				

- Analysis of Variance Table for Carbohydrate

Source	DF	SS	MS	F	P
Varieties	7	83.390	11.9128	4.31	0.0074
Error	16	44.252	2.7657		
Total	23	127.641			
Grand Mean 83.045	CV 2.00				

APPENDIX C: Sample questionnaire administered to rice stakeholders and consumers

Kwame Nkrumah University of Science of Technology, Kumasi. Faculty of Agriculture

This questionnaire was designed to assess the quality of locally produced and imported commercial rice varietiesin Ghana. All information provided will be confidential

A. <u>IDENTIFICATION AND GENERAL INFORMATION</u>

1. Name of Respondent ………………………………………………………..
2. Type of respondent? a. Consumer ( ) b. Farmer ( ) c. Processor ( ) d. Trader ( )

   e. Others ( ) Specify ……………………………………………………….

3. Sex : Male( ) Female( )
4. Location:................................ Community…………………………

District………………………… Region……………………

5. Highest educational level reached (circle one answer only)

A. No education

B. Primary

C. Middle School Leaving Certificate/JSS,

D. Secondary / Technical School

E. Tertiary

B. <u>CONSUMPTION DATA</u>

6. Do you consume rice? Yes ( ) No ( )
7. If yes, how often do you consume rice? Daily ( ) 2 times a week ( ) 3times a week ( ) 4 times a week ( ) Fortnightly ( ) Monthly ( )
8. Which of these two varieties do you prefer? Local ( ) Imported ( ) 9. What are your reasons for the choice taken above?

   i. ……………………………………………………………………

   ii. ……………………………………………………………………

   iii. ……………………………………………………………………

10. Do you consume local rice? Yes ( ) No ( ).
11. If yes, how often do you consume local rice? Daily ( ) 2 times a week ( ) 3times a week ( ) 4 times a week ( ) Fortnightly ( ) Monthly ( )
12. What varieties of local rice do you consume

…………………………………………………………………………………………

13. What are your reasons

…………………………………………………………………………………………

…………………………………………………………………………………………

14. How long have you been consuming this varieties (years)? _____________
15. Do you face any problem in consuming local rice? Yes ( ) No ( ).
16. If "yes" what are some of the problems?

…………………………………………………………………………………………

…………………………………………………………………………………………

17. Do you have any standards for measuring rice quality? Yes ( ) No ( )
18. If you answered yes, please indicate which of the following (**tick all that may apply**)

a. Purity b. colour c. aroma d. flavour e. texture f. Swelling

19. How do you get your supply of local rice? a. From the market ( ) b. Sales outlet ( )

c. Restaurant ( ) d. Supermarket ( ) e. Rice Farmers ( ) f. Others ( ) Specify___________________________

20. Do you consume imported rice? Yes ( ) No ( )
21. If you answered yes to the question above, please indicate which brand(s) of imported rice you often consume:

……………………………………………………………………………………

22. If the price of local rice is the same as that of imported rice, which one would you prefer?

a. Local rice ( ) b. Imported rice ( ).

23. Why? ____
24. Would you like to see more improvement in the production of local rice? Yes ( ) No ( )
25. If yes, what improvement do you want to see?

____

____

26. Do you know the differences in mouth feel or quality of rice from different countries? Yes ( ) No ( )
27. Which of the factors below influence your purchase of rice (**tick all that may apply)**

a. Aroma ( ) b. Taste c. Appearance ( ) d. Nutrients ( ) e. Texture ( ) f. Others ( ) Specify ___________________________________

28. How do you agree or disagree with the following characteristics of the local rice you consume. Please circle appropriately.

Strongly Agree (5), Agree (4), Undecided (3), Disagree (2), Strongly Disagree (1)

	Strongly Agree	**Agree**	**Undecided**	**Disagree**	**Strongly Disagree**
Moderate Price	5	4	3	2	1
Tasty/Palatability	5	4	3	2	1
High Swelling Capacity	5	4	3	2	1
Readily Available	5	4	3	2	1
Odour	5	4	3	2	1
Well-Polished	5	4	3	2	1
Availability of Dirt	5	4	3	2	1
Long Shelf Life	5	4	3	2	1
Perfumed/aromatic	5	4	3	2	1
Hard	5	4	3	2	1
Sticky	5	4	3	2	1
Loose particles	5	4	3	2	1
White	5	4	3	2	1
Coloured/brownish	5	4	3	2	1
Cooking time	5	4	3	2	1
Water holding capacity	5	4	3	2	1

C. <u>PRODUCTION DATA</u>

29. How long have you been cultivating rice? ……………………………… Years.

30. What variety of local rice do you Produce/Cultivate? …………………………

31. How many acres did you cultivate in

a. 2011............ b.2012………………… c. 2013…………………... d. 2014.......................

32. How many bags did you realize in (milled or paddy)

a. 2011…………… b. 2012………………. c. 2013…………………. d. 2014……………………..

33. At what moisture content or stage do you harvest your rice? a. 12% ( ) b. 14% ( ) c. 16% ( ) d. 25% e. When rice is very dry and shattering ( )

34. How early do you sell your produce after harvest (months)?

a. 0 month after harvest b. 1 months after harvest c. 2 months after harvest d. 3 months after harvest e. 4 months after harvest f. 5 months and above after harvest

35. How long do you store your rice?

a. 3months ( ) b. 4months ( ) c. 5 months ( ) d. 6months ( ) e. 7months & above ( )

36. Do you experience mould growth during storage?

a. Yes b. No

37. If Yes, at what month during storage? ....

38. If No, how do the grains appear?

……………………………………………………………………………………………

……………………………………………………………………………………………

39. In what month of the year is mould growth high? ....

40. How do you thresh your rice? a. On bare floor ( ) b. On tarpaulin ( ) c. In threshing boxes ( ) d. Use of mechanized thresher ( )

41. Do you winnow and clean your paddy before storage or milling?

a. Yes ( ) b. No ( )

42. Do you clean your facility before storage or processing?

a. Yes ( ) b. No ( )

43. Give reason(s)

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

D. <u>END MARKET DATA</u>

44. Do you sell locally produced rice? Yes ( ) No ( )

45. What is the commonest or most frequent rice variety that is demanded by consumers?

…………………………………………………………………………………………………..

46. Why is this the most preferred variety by consumers?

…………………………………………………………………………………………………

…………………………………………………………………………………………………