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KUMASI

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DEPARTMENT OF HORTICULTURE

EFFECT OF PARBOILING ON THE QUALITY OF PROCESSED DEGAN RICE (*Oryza spp*)

A Thesis submitted to the Department of Horticulture, Kwame Nkrumah University of Science and Technology in Partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (POSTHARVEST TECHNOLOGY)

BY

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DECLARATION

I, Mr. Issah Mohammed Hardi hereby declare that this project work was undertaken entirely by my own effort and that the results are my on research except for references to other academic, project reports and literary works, which have been properly sited and dully acknowledged.

ISSAH MOHAMMED HARDI ....

(Name, ID **PG3121009)** Signature Date

I hereby declare that I have supervised the student in undertaking the project submitted herein and confirm that the student has been permitted to present it for assessment.

Mr. Francis Appiah ....

(Supervisor**)** Signature Date

Dr. B. K. Maalekuu ....

(Head of Department**)** Signature Date

DEDICATION

This project work is dedicated to the almighty Allah

This work is also dedicated to my parents and siblings, to my wife Zenab and my children: Issah Hamdan Katari and Issah Nihad Yalsuma who in diverse ways helped me to go through this course successfully. It is also dedicated to the Pegu family for their immense support throughout my education. This token is to inspire you not to give up on your dreams. Remember quitters have never won, winners will never quit.

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I owe a debt of gratitude to some personalities who in diverse ways contributed to the success of this work.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

A study conducted to determine the perception of stakeholders in the production of parboiled rice in the Tamale metropolis of Ghana. It also sought to assess the effect of parboiling on Degan processed rice with respect to quality parameters such as physic-chemical and functional properties as well as eating characteristics. During the study a survey and laboratory work were done. Economic analysis of parboiled rice was also done. The analysis of results of the data collected from farmers showed that all (100%) of the respondents were women in the parboiling industry with many years of experience in parboiling. The farmers indicated that parboiled rice has much more foreign matter. The study revealed that parboiling was effective in improving the physic-chemical properties of rice such as head rice yield, percent whole grain, percent adulterants and weight of 1000 grains. Parboiling had varied effect on functional properties. These are swelling power, Water Absorption Capacity (WAC),Oil Absorption Capacity(OAC) and Least Gelation Capacity (LGC).Economic analysis of parboiled rice showed that parboiling has the potential of improving the economic well being of farmers if combined with new existing technology. It is recommended that improved technology be adopted in the parboiling industry to improve rice quality and subsequently improve financial status of farmers.

CHAPTER ONE

INTRODUCTION

1.1: Overview

Rice (*Oryza sativa L.*) is the staple food for nearly two-thirds of the World's population (Wynn, 2008). It is reported that the World's stocks of stored rice grain have been falling relative to each year's use, because the consumption has surpassed production (Roy and Shiina, 2010). China and India account for over half of the world's supply of rice and consumption, with China producing 182 million tons (28.8%) of global rice harvest, closely followed by India with 136.5 million tons (21.6%) of global harvest. The production of rice worldwide stands at 685 million tons as at 2008 (Daniel, 2008).

Rice is one of the leading foods in the world and fourth most widely produced cereal in Ghana after maize; sorghum and millet, contributing about 10.8% of total cereal production (Obeng, 1994). According to WARDA (2007) Ghana was below 25% self-sufficiency in rice production. This means that Ghana still require huge imports to supplement the difference in local demand (Manful *et al*, 1998).

Rice as an economic crop is important in household food security, nutritional diversification, income generation and employment; hence it helps in poverty alleviation. The crop has become an important income generating commodity for women in the three northern regions of Ghana as they are involved throughout the production chain from planting to processing.

Even though local rice is said to taste better, many urban dwellers prefer imported rice despite its high price. The situation has been attributed to the fact that imported rice is perceived to be of higher quality. Imported white rice dominates rice consumption in Ghana (Manful *et al*, 1998).It is estimated that the country spends about US$100 million annually to import the rice needed to meet more than half of Ghana's rice requirement.

The introduction of "eat Ghana rice" has brought about the sensitization of farmers the need to adopt new ways of processing paddy locally to the level of quality of foreign rice. This will lead to the release of pure breed, stone-less, foreign material free and correctly milled grains of rice in the country. The adoption of these local ways of processing rice has increased the consumption of local rice to 239400 tons of milled rice a year in Ghana (Obeng, 1994).

Modern parboiling is said to increase the quantity and quality of rice because it reduces the number of broken grains at milling, thereby obtaining higher milling yield. It also creates physical and chemical changes in the grain that makes it more nutritious and easier to sell and cook. The parboiled produce exhibit several advantages over non-parboiled product such as the strengthening of kernel integrity, increased milling recovery, prevention of the loss of nutrients during milling and improved shelf life as well as prevention of the proliferation of fungus and insects (Bhattacharya, 1985).

Parboiling of rice is a processing technique that involves three stages of; soaking paddy over night, followed by a short period of steaming to complete gelatinization of the starch and drying. These processes require more energy and longer time (Velupillai *et al.*, 1989) and has some serious draw backs such as foul odour due to microbial fermentation during the prolonged soaking and also loss of dry matter (Dandekar, 2010).

Demands for parboiled rice are increasing because of its nutritional value and the health claims associated with it. The protein content of rice is low but studies have shown that it is comparable to that of wheat, while its digestibility is high compared to other cereals (Wan,2008).

1.2: Problem Statement

In northern Ghana, paddy rice is parboiled (due to much drier climates) to reduce breakage on milling. The majority of rice produced in these regions is parboiled in 85kg batches, by rural women using traditional technologies (metal cooking pots, open fires, earth drying floors). The paddy is grown by small-scale farmers who, typically, cultivate only 1-2 acres of rice. Rice production and processing, therefore, contributes to livelihood sustainability of the rural poor in these regions.

In Northern Region of Ghana, the local variety commonly cultivated is degan rice; it is utilized mostly at household level where it is consumed as boiled rice. It is mainly processed by parboiling; parboiling is the hydrothermal treatment of paddy. It has been reported by many authors (Adeyemi *et al.,* 1986) that parboiling affects the physico-chemical and cooking qualities of rice but no work has been done on this local variety which is economically important in this part of the nation. Since many varieties of rice exist, there will be differences in the effects of parboiling on the different varieties. The quality of local parboiled rice has also been shown to be very variable, and not competitive with imported milled rice (Tomlins *et al*., 2002). The hypothesis of this study was

- Parboiled Degan rice is of poor quality as it has a lot of foreign matter and weeds seed, stones, mixed varieties and broken grains during milling.
- The processing in parboiling affects both functional and physic-chemical properties
- Cooking time and eating characteristics of Degan rice.

1.3: Objectives of Study

Main Objective

The objective of this study was to assess the effect of parboiling on quality of degan rice in the Northern Region of Ghana

Specific Objectives

The specific objectives of the study were to assess the:

1) physical properties of parboiled rice
2) functional properties of parboiled rice
3) effect of parboiling on eating quality of rice and
4) determine the cost benefit analysis of parboiled rice in the region

1.4: Justification of the Study

Asian countries exhibited about 54 brands of parboiled rice in the world market that earned the country a good foreign exchange (IndiaMart, 1996). Indiamart further reports that their quality long grain parboiled rice is free from all kinds of dust, insects, organic matter such as weed seed. In addition they ensure that the rice is preserved at standard room temperature with exact moisture.

Parboiled rice appears to offer an option for West African countries to reduce the importation of rice annually and help increase domestic rice production (Felix, 2009)

Parboiling involves the soaking of paddy in warm water overnight and followed by a short period of steaming, drying and finally milling to get a product (rice). This increases the quality and quantity of rice because it reduces the number of broken grains at milling (Dorinder, 2009). Parboiling is therefore a hydro thermal process (uses water and heat) which is carried out to improve the nutritional status of the product, to reduce breakage in milling, to change the cooking characteristics and to impart different eating characteristics.

CHAPTER TWO

LITERATURE RREVIEW

2.1: Rice Production

2.1.1: Global Production

Rice (Oryza sativa L.) cultivation according to the USDA, (2009) is the principal activity and source of income for millions of households around the globe, especially countries of Asia and Africa. They highly depend on rice as a source of foreign exchange earnings and government revenue. Rice is one of the most important crops produced among the cereal crops worldwide, the second largest produced cereal in the world and its production is geographically centred in Western and Eastern Asia. Asia is the largest producer of rice, accounting for 90% of the world's production and consumption. China and India account for over half of the world's supply of rice and consumption, with China producing 182 million tons (28.8%) of global rice harvest, closely followed by India with 136.5 million tons (21.6%) of global harvest. The production rate of rice worldwide stands at 685 million tons as at 2008 (Daniel, 2008).

2.1.2: Rice Production in Africa

It is estimated that rice sustains the livelihood for 100 million people and its production has employed more than 20 million farmers in Africa (WARDA, 2005). Africa's rice production has not been able to match growth in demand. The slow growth in domestic rice production has been attributed to the very low yield being achieved by West African farmers. There has been modest growth in production achieved in the 1990s and this has been due solely to an expansion of cultivated area at an annual rate of 3.5% (Lancon and Erentien, 2002).

In West Africa, two to three rice crops can be grown annually under irrigated conditions and in some cases, five crops are cultivated over a period of two years. Upland rice is grown on free draining soils where the water table is permanently below the root zone of the rice plant and the crop depends entirely on rainfall. Under these conditions, the rice crop can be grown only once a year during a single rainy season. In some parts, of West Africa, bimodal rainy season permits two crops of rice/year, while rice ratooning is also practiced in the areas with approximately 1 600 mm/rainfall per annum. In sub-Saharan Africa, rice is produced in five main ecosystems, namely rainfed uplands, rainfed lowlands, inland swamps, irrigated ecosystem and mangrove swamps (Otoo and Asuboateng 1996).

2.1.3: Rice Production in Ghana

According to Mobil and Okran (1985), rice has been cultivated in Ghana for a long time. During the 17th and 18th centuries, it was already one of the major commercial food crops. It was estimated that an annual average of 34, 600 hectares of land area was under cultivation within the periods of 1960–64, with an annual average paddy production of 35,800 tonnes (Ibrahim, 1984). Domestic rice production in Ghana has been consistently less than its consumption needs. Demand for rice has outstripped supply due to the population increase and to improved standards of living, as well as poor production and marketing arrangements on the supply side. Consequently, government imports up to 200% of local rice production to compensate for the shortfall in supply, which drains the country's scarce foreign exchange (Dogbe, 1996). Between 1989 and 1996 Ghana was reported to be only 15.1% self-sufficient in rice production after dropping from 48.3% between 1970 and 1974 (Oteng *et al*., 1994). According to WARDA (2007), Ghana was below 25% self-sufficiency in rice production. Imported white rice dominates rice consumption in Ghana. It is estimated that the country spends about US$100 million annually to import the rice needed to meet more than half of Ghana's rice requirements. This means that Ghana still require huge imports to supplement the difference in local demand (Manful *et al*, 1998).

Table 2.1: Area harvested Yield and Production per tonnes of rice from 2000-2009 in Ghana**.**

Year	Area harvested (Ha)	Yield (Hg/Ha)	Production (tonnes)
2000	115200	21588	248700
2001	136039	20185	274596
2002	122810	22799	280000
2003	117000	20411	238810
2004	119392	20253	241807
2005	120000	23916	287000
2006	125000	20000	250000
2007	108930	17014	185340
2008	132800	22734	301920
2009	162400	24103	391440

(Source: FAOSTAT, 2011)

The introduction of eat Ghana rice has brought about the sensitization of farmers the need to adopt new ways of processing paddy locally to match the quality of foreign rice. This will lead to the release of pure breed, stone-less, foreign material free and correctly milled grains of rice in the country. The adoption of this local ways of processing rice has increased the consumption of local rice to 239400 tons of milled rice a year in Ghana (Obeng, 1994). Currently Rice is important to Ghana's economy and agriculture, accounting for nearly 15% of the Agricultural Gross Domestic

Product (AGDP). Obeng (1994) also reported that rice production in Ghana is within some distinct rice ecosystems which include:

1. Rain fed dry lands
2. Rain fed low lands/hydromophic
3. Inland groups and valley buttons; and
4. Irrigated paddy.

Over 60% of the crop is grown in two Northern regions; Upper East and Northern region with 75% of production from rain-fed land, 10% of production from irrigated fields and the inland groups and valley bottoms contributing 15% (Seini, 2002).

The rice sector is an important provider of rural employment. The crop has become an important income generating commodity for women in the three northern regions of Ghana as they are involved throughout the production chain from planting to trading.

2.2: Rice Uses

According to Shilpa (1996), the uses of rice worldwide is great; principal among them include; staple food (Nutrition) both human and animals. Countries also benefit from rice production by getting foreign exchange, and above all medicine. The grain products of rice include: flakes, rice flour, starch, rice milk, rice cakes, and the extended uses of rice include: rice husk for fuel, rice bran for animals feed, broken rice used as snacks in Thailand and rice beverage.

2.3: Rice Processing in Northern Region of Ghana

2.3.1: Pre-harvest and Postharvest Factors that Affect Processing

Manful *et al*. (1998) identified the following pre-harvest and postharvest rice production practices as the main factors affecting rice quality in northern Ghana.

According to them much of the rice is grown from impure seed, with high levels of varietal admixture, resulting in uneven grain maturity at harvest and variation in size and shape of the paddy grain. Admixtures therefore affect the quality of milled rice, both raw and parboiled. Some varieties have a greater husk-kernel proportion resulting in a low milling outcome.

Many non-irrigated rice growing areas suffer from water deficits that may affect grain filling and maturation and therefore have a subsequent effect on the quality of milled rice

Lodging on an extensive scale can affect the quality of the milled rice, as grains that come in contact with the soil and water are proned to fungal attack and discoloration.

Manual harvesting appears to have little effect on paddy quality. Grain harvesting by combine harvester is of inferior quality with a larger proportion of broken grains and organic contamination (weed seed, chaff)

In many areas, threshing is carried out by laying the panicles on dirt floors on the farms. The panicles are then beaten with sticks to remove the paddy grains and the threshed grains are swept off the ground. There is, inevitably, considerable contamination with stones and mud.

Paddy drying is often done on clay floors as very few farmers have tarpaulins or concrete drying floors. The effect of this is more stones in the paddy after collection and bagging.

Over-drying, either pre-or post-harvest and the consequent cracking of the grain result in a high percentage of broken grains in milled rice. Good parboiling can largely overcome this problem.

Paddy is usually traded in relatively small quantities. Price is dependent on supply of available paddy (seasonal variation), not on paddy quality.

2.3.2: Rice Processing Sector in Northern Region

Rice processing in northern Ghana is grouped into three based on level of operation namely; household processing, small-medium scale custom milling and large scale market oriented rice processing. The Engelberg huller is the most widely used rice miller in northern Ghana (Manful *et al.*, 1998).

Rice is mostly processed in the house for domestic consumption, especially in the rural areas where processing is seen as labour intensive. In this method, the raw material is put in a wooden mortar and pounded by one or more women. The husk is removed from the pounded grain by hand winnowing, where wind blows the litter particles away as the grain is poured from one container to another. The unshelled paddy is further removed by skilful use of the winnowing basket and re-pounded until all husk is removed. The brown rice is then pounded again to remove the bran. Household rice processing usually does not enter the marketing chain since most of the processed rice is for home consumption.

Small-medium scale rice processing dominates the rice processing sector in Ghana. This, coupled with large scale market oriented rice processing is used mainly to supply the market with milled rice. In these systems, paddy is milled for a set price. Milling is done by a chiness operated electric or diesel motors. Pillaiyar (1996) stated that factors influencing milling efficiency include (i) the uniformity of the paddy, (ii) the variety of paddy shelled, (iii) the condition of the paddy, (iv) the type of machine, (v) the condition of the mill and, (vi) the skill of the mill operator.

2.3.2.1: Parboiling

Parboiling is an ancient method of rice processing, widely used in the developing countries like Bangladesh, India, Sri Lanka, and in some rice exporting countries. Parboiling involves the soaking of paddy overnight followed by a short period of steaming, drying and finally milling to get a product. Parboiling is therefore a hydro thermal process (uses water and heat) which is carried out to improve the nutritional status of the product, to reduce breakage at milling, to change the cooking characteristic and to impart different eating characteristics (Dorinder, 2009). The process increases the quality and quantity of rice because it reduces the number of broken grains at milling (Dorinder, 2009). Parboiling treatment induces various physicochemical changes in paddy rice which play an important role in the subsequent storage, milling, cooking and eating qualities (Kimura *et al.*, 1995). Parboiling gelatinizes the rice starch, improves the hardness of the rice upon drying, minimizes the breakage losses and thus increases the milling yield (Roy *et al.*, 2004). As Araullo *et al* (1976) summarized the importance of parboiling as follows:

1. To increase the total and head rice yield of paddy.
2. To prevent loss of nutrient during milling.
3. To salvage wet or damage paddy.
4. To prepare the rice according to the requirements of consumers in certain parts of the world.

Over-parboiling however, results in over-opening of the husk components followed by bulging out of the endosperm which initiates surface scouring during milling and the resultant ground particles being lost into the husk and bran (*Roy et al*., 2011).

2.3.2.1.1: Parboiling in Northern Region of Ghana

Parboiling of paddy is a very important rice processing method in northern Ghana. This is due to the high temperatures in the area. Rice parboiling is mostly carried out by women, and done more often in iron pots on open fires. The process is not standardized. Variations in techniques exist among various women and the resultant product varies in quality. The process mainly consists of soaking paddy over night, followed by a short period of steaming to complete gelatinization of the starch and drying.

Rice soaked in water at ambient temperature (20-30°C) will take 36 to 48 hours to reach 30 per cent moisture content. In hot water (60-65°C), it will take only two to four hours. If soaking time is too long, part of rice dissolves in water, the seed begins to germinate, and starch fermentation occurs. Water temperature and length of soaking time affect the solubility of substances in rice as well as colour, smell, and taste. . During hot water soaking (60-65°C), the grain absorbs moisture faster and reaches a moisture level of 30-35 per cent in two to four hours depending on the variety. Hot soaking keeps the grain at a higher temperature which will reduce the steaming time needed to complete the process. The moisture content of paddy increases to about 38 per cent during steaming. When heating paddy with non-pressurized small variations are found in colour, quantity of soluble starch, and the amount of swelling of the milled parboiled rice. Heating has a considerable effect on colour. When the steaming temperature exceeds 100°C, the colour becomes considerably deeper and the grain becomes harder. Longer steaming times also cause rice to be harder and darker

2.3.2.2: Drying

Drying should be done to 14 percent moisture for safe storage and milling. Parboiled rice is more difficult to dry and requires energy than field paddy because its moisture content is much higher, however, higher air temperature help reduce the drying time. Most parboiled paddy is sun-dried on large drying floors by large number of people who are required to constantly turn and mix the paddy to achieve rapid, uniform drying. In contrast with field paddy, parboiled paddy requires air temperatures of up to 100°C during the first drying period. During the second period air temperature should be kept below 75°C. Moisture reduction takes place rapidly during the first part of drying from 36 to 18 per cent moisture level, but is slow from 18 to 14 per cent.

2.3.2.3: Milling

Dehusking and milling process removes the outer part of paddy rice (husk and bran) to make it edible. It has been reported that different types of liner significantly affect the husking performance (Shitanda *et al.*, 2001). It has also been reported that the Engleberg-type or steel hullers are no longer acceptable in the commercial rice milling sector, as they lead to low milling recovery and high grain breakage (IRRI, 2003). In the Engelberg or huller type mill, dehusking and milling are performed in one step with greater grain breakage. The energy consumption during the dehusking process is also caused by the severity of the steaming treatment and it tends to have decreased with the increase of steaming time (Roy, 2003).

Manful *et al*., (1998) reported that, transforming paddy to milled rice in Northern Ghana costs traders over GH¢ 50 per bag of which the cost of processing (including parboiling) constitutes 82%. About 65% of the cost of processing may be attributed to parboiling and the rest to milling and winnowing charges. Family members are employed for rice processing. Family labour is not valued and processers tend to lose. Mills are mostly owned by men and milling is profit oriented.

Jodari (1996) argues that knowing the information on rice varieties with similar grain characteristics will help minimize milling and quality losses; this subsequently will improve handling and storage. He also argues that, the mixing of long, medium and short grain types affect milling yield. Grain length in rice plays an important role in determining rice appearance, milling cooking and easy quality (Wan, 2008).

2.4 Quality Characteristics of Milled Rice

2.4.1 Head Rice and Milling Yield

Rice as a commercial staple food for most people in the world has to be processed and milled well to get the needed market and profit. Haroon (2009) reported that for rice to be transformed into a suitable form for human consumption, it has to be done with utmost care to prevent breakage of the kernel and improve milling and recovery rate. Majority of rice produced in northern Ghana is subjected to parboiling to avoid loss both qualitatively and quantitatively. Quantitative or physical losses is manifested by low milling yield and recovery while low head rice yield or high percentage broken of kernel reflects the qualitative loss in rice grains. Parboiling therefore is a method to improve head rice yield at milling. (Haroon, 2009). Different methods of milling produce different milling yields though the rice may be processed with the same method (parboiling). Mechanical milling produce a high milling yield, but the rice produced from this type of milling has low nutritive rate as compared to the traditional method of milling which produces low milling yield but with rice with high nutritive value (zenith, 2009).

2.4.2 Cooking Time and Water absorption Capacity

Vivian (1999) reported that water absorption rate varied among varieties of rice and this is partly due to soaking time of the rice kernels. Juliano (1985) stated that parboiled rice has low water absorption capacity than raw rice, thus retains better shape, less sticky, more consistent and loses fewer solids during cooking. Processing conditions such as mode and degree of soaking of paddy influence water uptake capacity of the rice grain. The cumulative water absorption capacity of rice is higher for the lower levels of steam pressures for almost all rice varieties. The cooking time also varied from 10-30mins. The study also revealed an increase in water absorption capacity with increased cooking duration for all the steam pressures although the rate of increment between the initial and final cooking time were higher for higher levels of steam pressures. They concluded that this could be as a result of the difference in severity of parboiling arising from the different levels of steam pressures (Ali and Bhattacharya, 1991).

2.4.3 Swelling Power and Solubility

Tung Chien (1988) reports that the swelling power of rice is dependent on the variety of rice and the treatment the rice is subjected to. The amylase content of the rice variety also contributes significantly to the swelling power. Rice varieties cooked under high temperature of eighty degrees Celsius have high swelling power as compared to those under twenty degrees Celsius and this is as a result of the high amylopectin content. Rice soaked under low temperature had low peak gelatinization and swelling capacity. The moisture content of rice and level of dryness also determines the water absorption capacity. Rice bran has high quality functional properties. Rice brand mixed with bread improved the quality of bread and made it attractive to consumers. The product has high water holding capacity, water retention capacity, good swelling capacity and fat binding capacity and had good potential in various food products when incorporated (Manat,2011)

Wang *et al* (1999) reported that the nitrogen solubility of rice varies at varying pH levels. The solubility of Rice Bran Protein Isolate in water is minimum at pH 4.0 and increased gradually below pH 4.0 and pH above 6.0.The solubility continued to increase above PH 8.0 but at a slower rate, and at PH 10.0 did not show any significant increment.

2.4.4 Least Gelation Concentration

Processing of rice and the eating quality of the product are influenced by a number of functional properties. Bienvenido (1996) stated that, the ratio of amylose to amylo pectin in starch as indexed by apparent amylose content of milled rice is the chief influence on processing and eating quality. During parboiling, gelatinization starch granules swell irreversibly and can be raptured, releasing amylase (Nikuni, 1978). The formation of a gel is one of the principal factors that control the texture and quality of rice. The structure of the gel is determined by the starch concentration and the structure of the swollen starch granule, the amounts and the types of amylose and amyl pectin leached out from the granule, the interaction among amylose, amylopectin and the granule and the heating conditions such as temperature and heating period of the rice kernel (Yang *et al.,* 1987, Chang and Chang, 1988, Chang and Liu, 1991).

2.5 Flour Qualities

Studies on the utilization of seed proteins continue to gain attention due to the worldwide increasing demand for cheap and acceptable dietary protein, particularly for the low-income groups. Past studies on the nutritional composition and functional properties of seed flour proteins were carried out on the raw seed flours; benthseed, Pigeon Pea (Oshodi, 1992), and jackfruit (Morton, 1987). There is limited information on the effect of processing on the nutritional properties of seed flours (Nwanekezi *et al.*, 1994). In the culinary sense, flour is a powder made of cereal grains, other seeds, or roots. It is the main ingredient of bread, which is a staple food for many civilizations, making the availability of adequate supplies of flour a major economic and political issue at various times throughout history. Wheat flour is one of the most important foods in European, North American, Middle Eastern and North African cultures, and is the defining ingredient in most of their styles of breads and pastries. Significant gluten content produces lighter and softer baked products by embedding small gas bubbles. Scientific evaluation of essential factors relative to the quality of flour can be, and usually is made, by laboratory analyses. The amount of protein in particular flour is an indicator of bread-baking quality for plain white flour alone because rye flour, oat flour, and rice flour contain proteins unconnected with gluten, as does whole wheat flour with the proteins in the wheat germ. Flour dust suspended in air is explosive, as is any mixture of a finely powdered flammable substance with air and must be handled with care.

CHAPTER THREE

MATERIALS AND METHODS

3.1: Experimental Procedure

The experiment was done in two phases: A survey and a laboratory work.

3.1.1: Survey

A survey on the demographic background of people involved in parboiling, milling recovery/cooking characteristics of parboiled rice as well as the economics of parboiling was conducted at some selected communities in the Tamale Metropolis of the Northern Region of Ghana. The communities were Nyohini; Dungu; Malshagu; Lamashegu; Kumbuyili and Chogu. Fifty semi structured questionnaires aimed at collecting socio-economic data, information on milling out-turn as well as parboilers experience with parboiling; the parboiling process and the economics of parboiling were issued by well trained enumerators from the Northern School of Business in the Northern Region. Other important information collected included respondents' suggestion for the improvement of parboiling in the region.

3.1.2: Laboratory Work

3.1.2.1: Preparation of Paddy

Local Degan rice in paddy form was collected from local farmers in the Northern Region of Ghana. The paddy was winnowed to get rid of debris and cut weeds during harvest. It was then divided into two halves, one half was processed by Parboiling, drying and milling, the other half was processed by drying and milling only. The average initial moisture content of paddy was 13±2%. Before conducting the experiment, paddy rice packed in a 5 kg polyethylene bag were stored in a refrigerator at 10ºC.

3.1.2.2: Parboiling Process

3.1.2.2.1: Soaking Condition

The paddy was washed thoroughly about three times using clean water in every instance to get rid of chaff, stones, sand and unfilled panicles. It was then put into bigger pots and saturated with water. Three buckets of water to half bag of paddy was used. Fire was set under it and allowed to boil till bubbles appeared. The bubbling meant the soaking process is complete. The fire was extinguished and the paddy scooped into an empty pot of the same size covered and allowed stand overnight.

Figure 3.1: Washing of paddy

Figure 3.2: Warm soaking of paddy and scooping soaked paddy into another container

3.1.2.2.2: Steaming Condition

The second step of the parboiling process is steaming to improve rice moisture to 30–35% (Kimura, *et al*., 1995; Bhattacharya, 1985) and heat treatment also irreversibly gelatinizes the starch. The next morning after soaking a basket was used to drain the water off and the paddy was put into another pot with little water on fire and covered with jute sack for steaming to complete the gelatinization process. The steaming is complete when the paddy panicles split open during the process.

Figure 3.3: Steaming of soaked paddy

3.1.2.2.3: Drying Condition

The steamed rice was then dried on tarpaulin in the sun (34±1ºC, 58±5 %RH) and turned over frequently depending on the intensity of the sun with a rake for six hours, resulting in the final moisture content of 13±2%. After drying, samples were collected into the room to cool for another three hours and later stored in airtight polyethylene bags for moisture equilibration and hardness stabilization before milling as prescribed by Kimura *et al*. (1995). This reduces breakages at milling.

Figure 3.4: Drying of parboiled rice

3.1.2.3: Milling

Milling was done with the Engleberg milling machine after which the rice was winnowed to separate the bran from the rice.

3.1.2.4: Flour Production

The milled rice was ground into flour using pistle and motar. The flour samples were passed through a 0.5 mm mesh size sieve and stored in airtight containers in a refrigerator at 4°C until needed for analysis.

3.1.2.5.1: Determination of Physicochemical Properties

3.1.2.5.1.1: Head Rice Yield

Approximately two weeks after drying, samples of non-parboiled and parboiled rice were milled using the Engleberg milling machine. The head rice yield was calculated as percentage of milled grains with respect to the paddy rice (Bello *et al*., 2004)

3.1.2.5.1.2: Moisture Content

The moisture content of rice was determined by the standard oven method. Three 2g samples were dried in hot air oven at 130ºC for 16 h (Mathews, 1962). Moisture content was expressed on a wet basis by subtracting the dry weight from the initial wet weight and calculating the mean values

3.1.2.5.1.3: Percentage (Breakage and Whole Grains)

Percentage of breakages and whole grains was determined after milling by sorting out the breakages in 10 g of sample by simple calculation in triplicates and calculating the mean values (IRRI, 2009).

3.1.2.5.1.4: Percentage Adulterants

Percentage adulterants were determined by sorting out adulterants in 10 g of sample by simple calculation in triplicates and calculating the mean values (IRRI, 2009).

3.1.2.5.1.5: Weight of 1000 grains

This was done by counting 1000 whole grains and calculating their weight in triplicates

3.1.2.5.2: Functional Properties

The following functional properties were studied; swelling power and solubility; water and oil absorption capacity; gelation capacity; bulk density.

3.1.2.5.2.1: Swelling Power and Solubility

This was determined with the method described by Leach *et al*. (1959) with modification for small samples. One gram of the flour sample was mixed with 10 ml distilled water in a centrifuge tube and heated at 80 °C for 30 min. This was continually shaken during the heating period. After heating, the suspension was centrifuged at 1000 × g for 15 min. The supernatant was decanted and the weight of paste taken. The supernatant was evaporated and the dried residue weighed to determine the solubility. The swelling power was calculated as: Swelling power = weight of the paste / weight of dry flour.

3.1.2.5.2.2: Water and Oil Absorption Capacity

The method proposed by Sabularse *et al*. (1991) was used with modifications to determine both water and oil absorption for small quantities. Two gram of rice was mixed with either 20 ml distilled water or oil in a test tube covered with a piece of cotton plug. The test tube was then placed in a thermostatically controlled water bath preheated to 97-99^o C for cooking the rice. This was then followed by cooling in water, draining of excess water, and the test tube placed upside down for 1 h and then weighed. Water absorption was calculated as increase in weight, and expressed as gram of water per gram of rice.

3.1.2.5.2.3: Bulk Density

A 50 g flour sample was put into a 100 ml measuring cylinder and filled to a constant volume. The bulk density (g/cm^3) was calculated as weight of flour (g) divided by flour volume (cm^3), (Okaka and Potter, 1979).

3.1.2.5.2.4: Gelation Capacity

This was done by the method of Coffman and Garcia (1977). Sample suspensions 2 – 20 % (w/v) were prepared in 5 ml-distilled water. The tubes containing these suspensions were heated in boiling water for 1 hour followed by rapid cooling under cold running tap water. The tubes were then further cooled for 2 hour at 7 °C. The least gelation concentration (LGC) was determined as that concentration when the sample from the inverted tube did not fall off.

3.1.3: Rice cooking and cooked rice Characteristics

3.1.3.1: Cooking time

Three lots of ten grams of rice sample was mixed with 70 ml distilled water in 100ml beaker and cooked at 97-99°C in cooker (Toshiba, Model RC-18R). After 10 min of cooking, ten grains were randomly removed and pressed between two glass plates. The number of translucent kernels were counted and recorded. Sampling was done at every 2 min interval and rice grains were analyzed until the end of the cooking cycle.

3.1.3.2: Sensory Evaluation

Rice samples were cooked and served to 22 discriminatory and semi-trained panellists. A scale of 1-7 was used, representing seven categories, where 1= dislike extremely and 7 like extremely. Sensory attributes of cooked parboiled rice that were subjected to evaluation were aroma, colour, texture, stickiness, taste and overall acceptability.

3.2: Statistical Analysis

The Statistical Package for Social Sciences (SPSS) version 17 was used to analyze the responses on farmers perception of postharvest losses. Analysis of variance (ANOVA) was performed on experiment data collected using GENSTAT Discovery Edition 3 and separation of treatment means was done using the LSD at 5% level of significance.

CHAPTER FOUR

RESULTS

4.1: Parboiling and gender

4.1.1: Gender, civil status and other activities performed by people involved in rice parboiling

Figure 4.1: Parboiling and gender

Figure 4.1 shows the gender balance among people involved in rice parboiling interviewed during the survey. All (100%) of those involved in parboiling were female which showed that parboiling, a post-harvest activity in the rice food chain is mainly dominated by females.

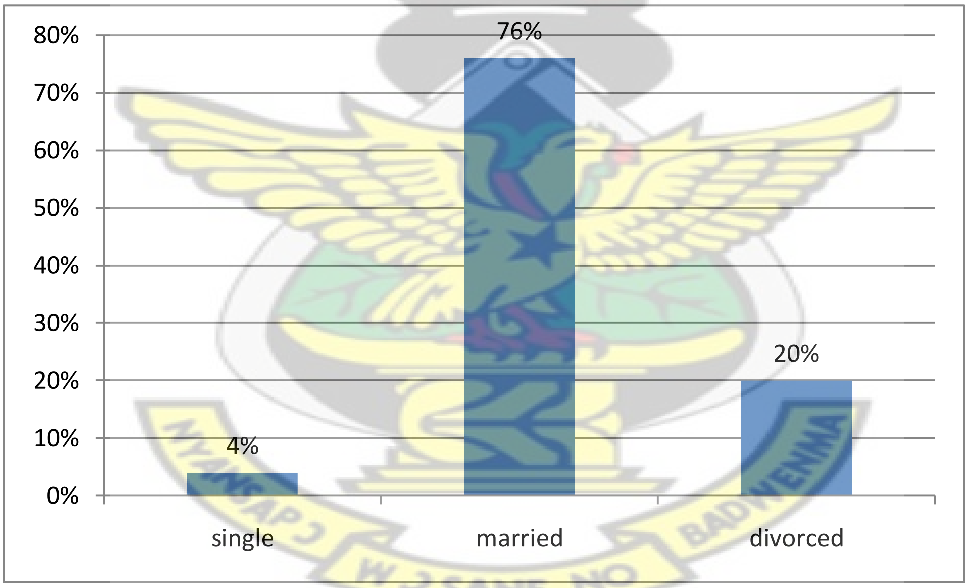

Figure 4.1: Civil status of parboilers

When asked of their marital status, 76.0% of the respondents indicated that they are married with only 4.0% that are single as shown in Figure 4.2

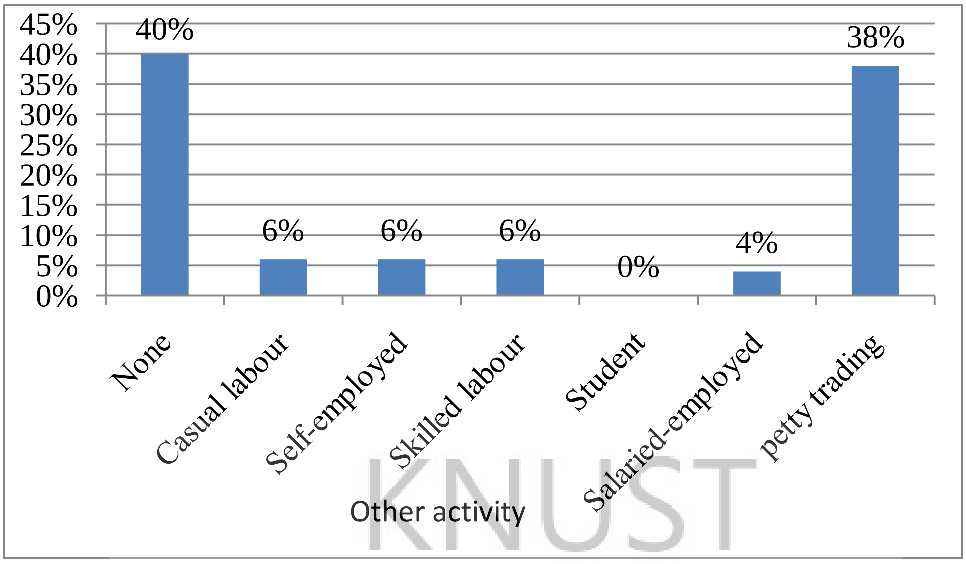

Figure 4.2: Other activities perfomed by rice parboilers

Out of the number of respondents who were interviewed, 40% of them depended solely on parboiling as their source of income, 38% were petty traders in addition to parboiling, 6% of them were self-employed, whiles 6% had casual labour and skilled labour respectively. 4% were salaried-employed with 0% being students.

4.1.2: Average age of respondents, their level of education and years of experience in rice parboiling

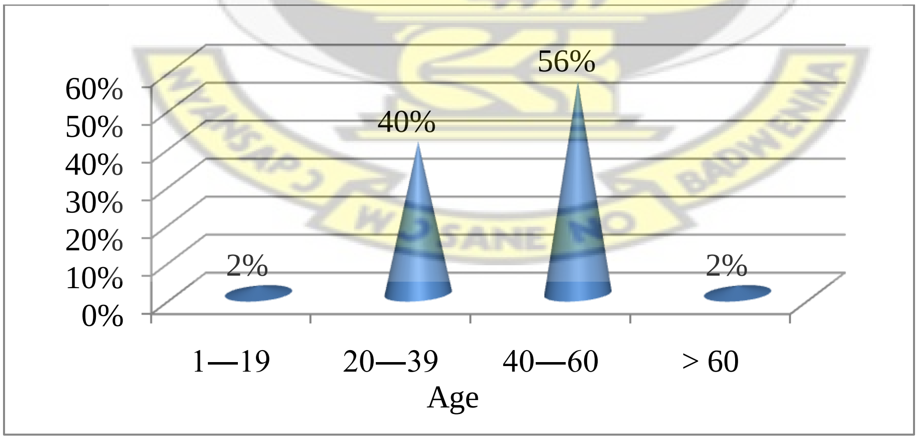

Figure 4.3: age of respondents

The results showed that majority of the respondents who were involved in parboiling fell within the age bracket of 40-60 representing 56% within this category, 40% fell in the age range of 20-39 with only 2% falling in the age groups of both 1-19 and above 60 years respectively.

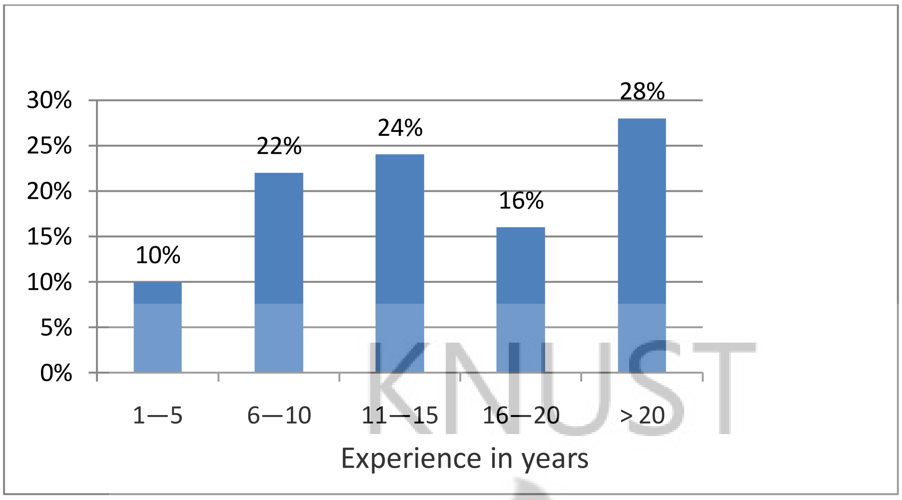

Figure 4.4: Experience in parboiling

The results obtained from the survey indicated that 28% of the respondents had more than 20years of experience in parboiling, 24% had 11-15years experience, 22% with 6-10years of experience 16% with 16-20 years experience with those having 1-5 years of experience being 10%.

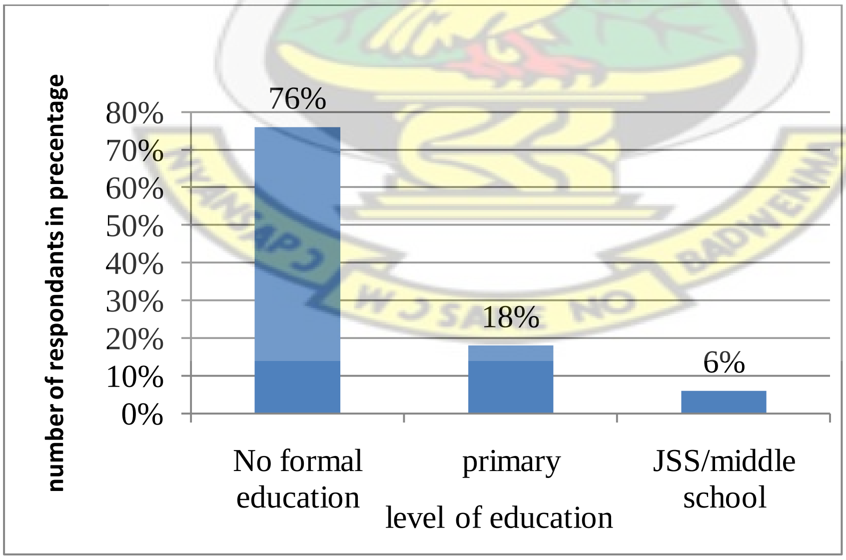

Figure 4.5: Level of education of Parboilers

Results of the survey indicated that 76.0% of respondents had no formal education with only 6% with formal education of up to the JSS/middle school level 18% had some formal education up to the primary school level (Figure 4.6).

4.1.3: Milling recovery of parboiled and non-parboiled rice

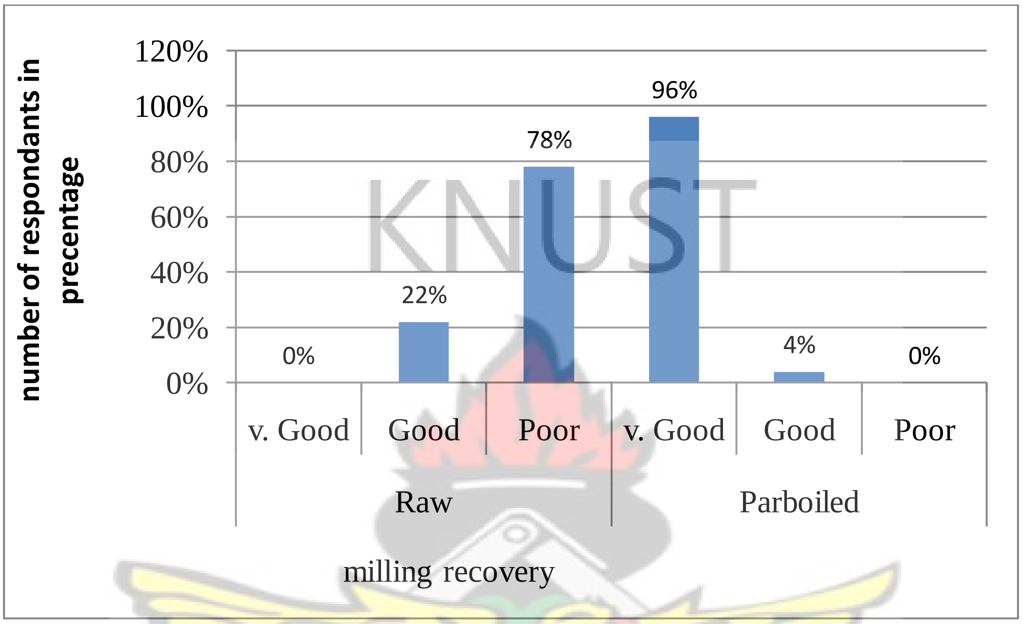

Figure 4.6: effect of parboiling on milling recovery

Figure 4.7 shows effect of parboiling on milling recovery, as many as 96% intimated that parboiled rice had a very good milling recovery whiles 4% said parboiled rice had a good milling recovery.However,22% showed that raw rice had a good milling recovery, with 78% of the respondents saying raw rice had poor milling out turn

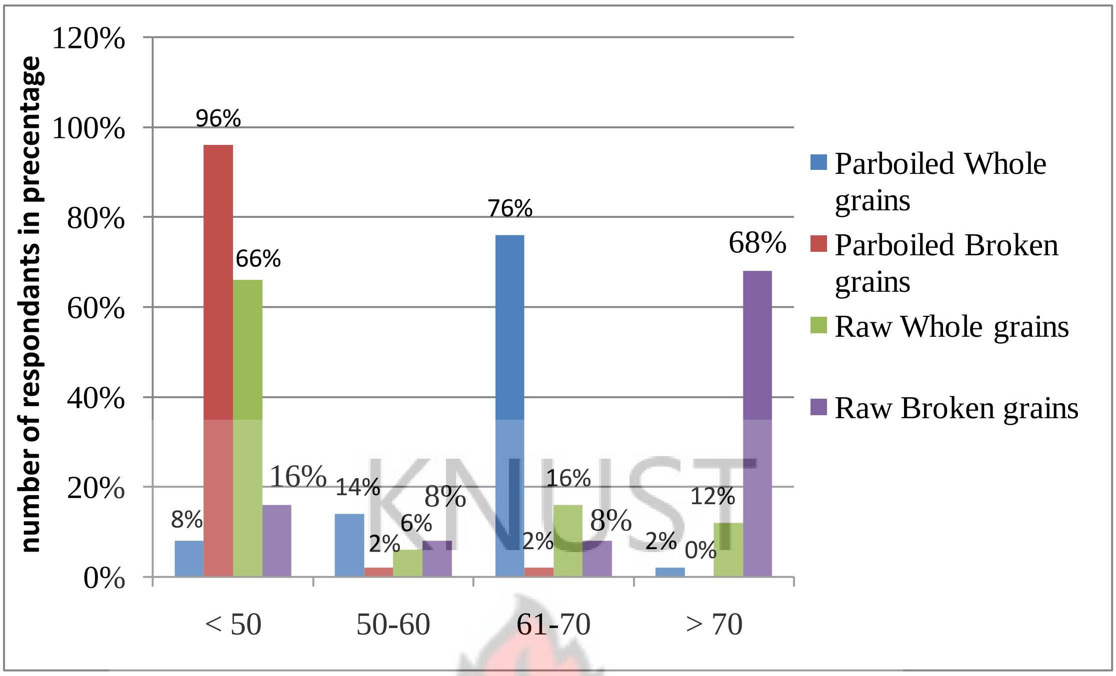

Figure 4.7: Percent whole and broken grains per bag of parboiled and non-parboiled rice

Figure 4.8 shows the percentage whole and broken grains of parboiled and raw rice, respectively. Less than fifty of the respondents said raw rice had 66% whole grains whiles 61-70 of them thought raw rice had 16% whole grains,50-60 of them also thought raw rice had 6% whole grains and more than seventy of them thought raw rice had 12% whole grains. More than seventy of the respondents said raw rice had 68% broken grains. Less than fifty of them said raw rice had 16% broken grains, 50-60 said raw rice had 8% broken grains and 61-70 also said raw rice had 8% broken grains.61-70 of the respondents said parboiled rice had 76% whole grains,50-60 said parboiled rice had 14% whole grains, also less than fifty of the respondents thought parboiled rice had 8% whole grains and more than seventy said parboiled rice had 2% whole grains. Less than fifty of the respondents said parboiled rice had 96% broken grains, then 50-60 of them intimated that parboiled rice had 2% broken grains and 61-70 of them also thought parboiled rice had 2% broken grains.

4.1.4: Cooking characteristics of parboiled and non-parboiled rice

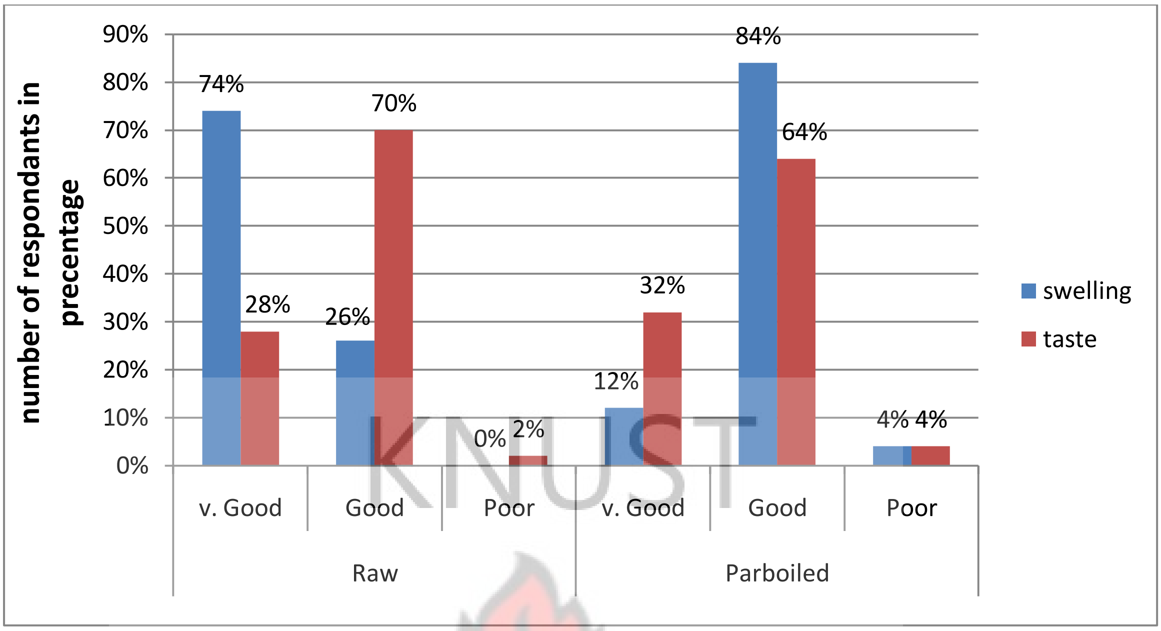

Figure 4.8: Effect of parboiling on cooking characteristics of rice

Figure 4.9 shows the cooking characteristics of parboiled and raw rice respectively.84% of the respondents said parboiled rice cooked good whiles 12% said parboiled rice cooked very good and 4% said parboiled rice cooked poor. As many as 74% said raw rice cooked very good, whiles 26% said raw rice cooked good. On the taste of rice, as many as 64% said parboiled rice tasted good, 32% said parboiled rice tasted very good. As many as 70% said raw rice tasted good whiles 28% believed that raw rice tasted very good.

4.1.5: Source of foreign material in milled rice

Figure 4.10 shows the source of foreign material into rice,44% indicated that foreign materials get into rice through threshing and drying,12% said foreign materials get into rice through harvesting,10% intimated that foreign materials get into rice through parboiling .8% of the respondents said foreign matter gets into rice through milling whiles 26% said none.

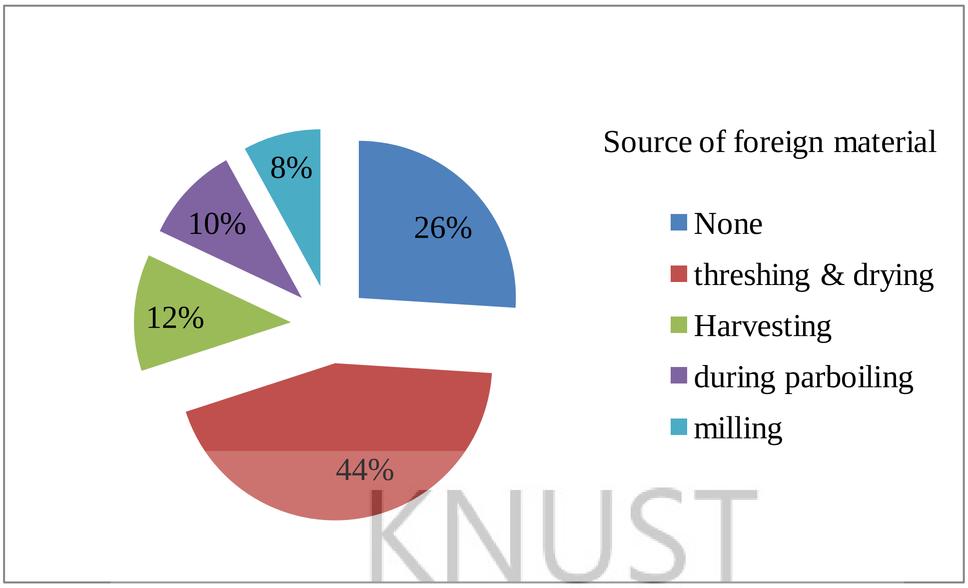

Figure 4.9: Source of foreign material in milled ric

4.1.6: Rice parboiling and marketing

4.1.6.1: Where parboiled rice is marketed

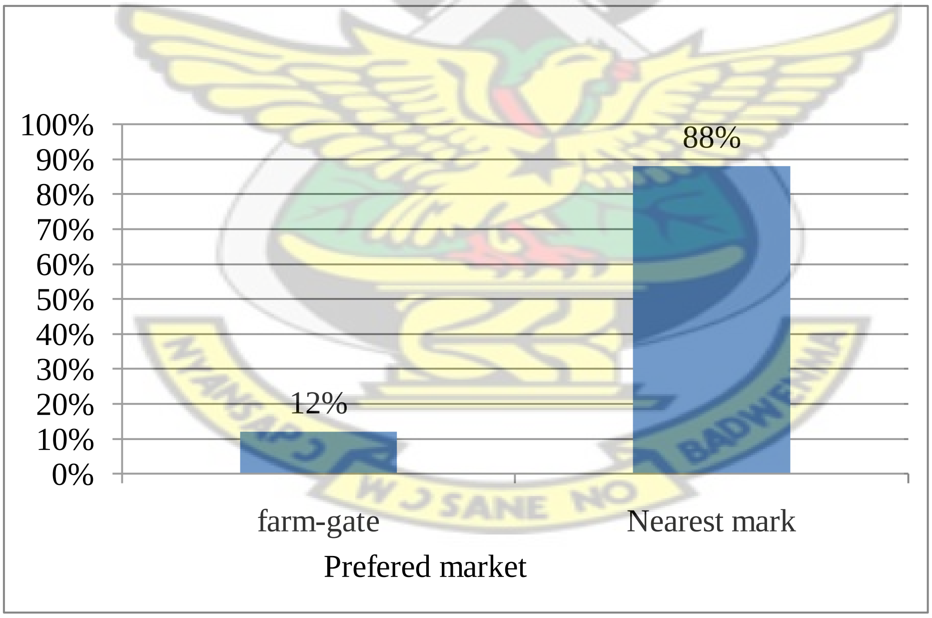

Figure 4.10: Where milled rice is sold

Respondents were asked where they normally sell their products after parboiling. The result showed that 88% of them sold off their product at the nearest available market whilst the remaining 12% sold off theirs at the farm gate.

4.1.6.2: Economically active household members who help in full time during parboiling

Seventy two percent of the respondents indicated that, they usually employed the services of 1-5 active household members who helped in full time during rice parboiling (Figure 4.12). The result also showed that, 22.0% of the respondents employed the services of between 6-10 people during rice parboiling with only 6.0% employing more than 10 people as shown in figure 4.12 below

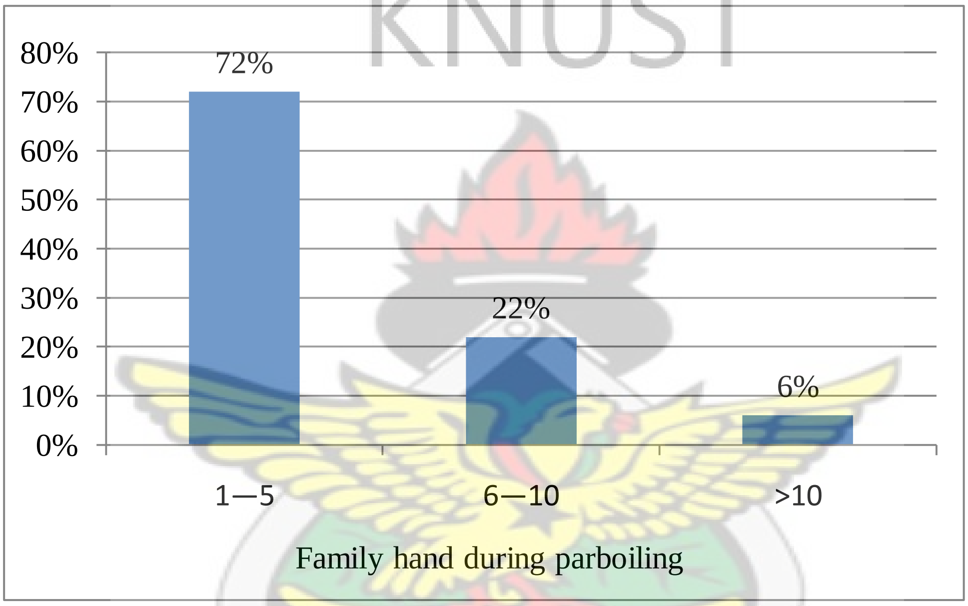

Figure 4.11: Active household members who help during parboiling

4.1.6.3: Cost of processing a bag of rice

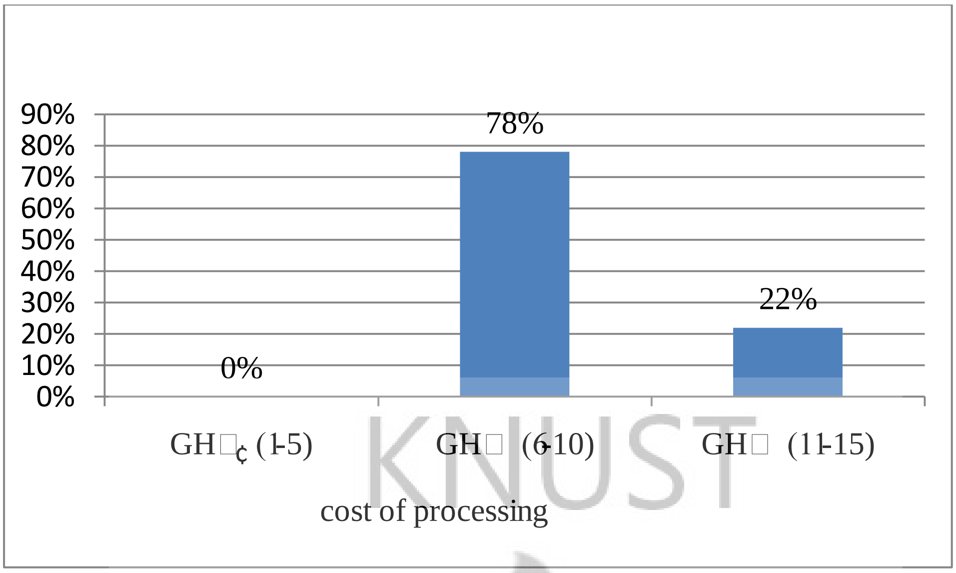

Figure 4.12: Cost of processing a bag of paddy

Respondents were asked the cost of processing a bag of rice. The results obtained indicated that 78% of the respondents spent GH¢ (6-10).22% spent as high as GH¢ (11-15) with 0% sending GH¢ (1-5)

4.1.6.4: Selling price per bag (50kg) of whole grains and broken grains rice

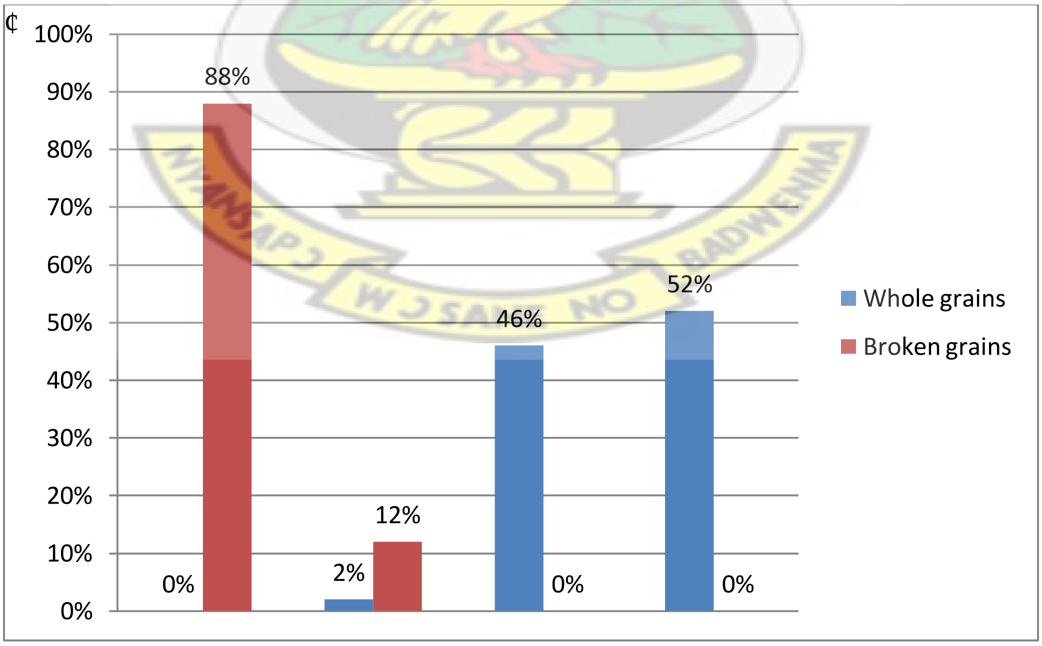

Figure 4.13: Selling price per bag (50g) of whole grains and broken grains rice

Figure 4.14 shows the selling price of whole grains and broken grains. From the figure, 52% of the respondents sold a 50kg bag of whole grain milled rice for between GH¢51-60. 88% of the respondents said they sold the broken grains of the same quantity for between GH¢30-40.

Table 4.1: Costs benefit analysis of rice parboiling in Northern Region of Ghana **(GH¢/bag)**

Variables	Raw	Parboiled
Cost of 80 kg paddy at farm-gate	40.00	40.00
Cost of transporting to store	0.50	0.50
Cost of processing [1]	2.92	8.33
Marketing cost [2]	1.00	1.00
Selling price of whole grains	22.14[B]	45.44[A]
Selling price of broken grains	19.28[D]	14.11[C]
Total selling price	41.42	59.55
Margin to trader	−3.00	9.72[E]

Source: Survey, 2011

Notes:

1 65% is made up of parboiling cost which includes firewood and water for parboiling, milling and winnowing charges

2 market tolls

A Conversion of paddy to milled rice is 74.40%, percent whole grains is 69.75% and 50kg whole grains costs GH¢54.72

B Conversion of paddy to milled rice is 52.84%, percent whole grains is 47.85% and 50kg whole grains costs GH¢54.72

C Conversion of paddy to milled rice is 74.40%, percent broken grains is 30.25% and 50kg broken grains costs GH¢39.20

D Conversion of paddy to milled rice is 52.84%, percent broken grains is 52.15% and 50kg broken grains costs GH¢39.20

E Includes money paid to active house-hold members who help during parboiling

4.2: Physico-chemical Properties

Table 4.2: Effect of parboiling on the physico-chemical properties of rice

Parameters	Parboiled	Non-parboiled
Head Rice Yield (%)	$74.40 \pm 0.46_A$	$52.84 \pm 0.19_B$
Moisture Content (%)	$10.83 \pm 1.04_A$	$9.33 \pm 0.29_A$
Whole Grains (%)	$74.47 \pm 4.70_A$	$27.77 \pm 0.92_B$
Adulterants (%)	$2.25 \pm 0.25_A$	$0.67 \pm 0.08_B$
Weight of 1000 Grains	$18.13 \pm 0.64_A$	$15.60 \pm 0.44_B$

Means of triplicates ± SD followed by different letters within a row is significantly different ($p < 0.05$)

Table 4.1 indicated that parboiled rice was significantly different from Non-parboiled at ($p<0.05$) in terms of head rice yield percentage with a value of 74.40 as compared to that of the non-parboil value of 52.84.

Whereas the moisture content of the raw rice was 9.33%, that of parboiled was 10.33%. Moisture content of the raw rice differed significantly ($p < 0.05$) from the parboiled.

The 1000 grain weight of the parboiled rice (18.13g) was significantly higher ($P<0.05$) than the raw (15.60g) Table 4.1

There was a significant ($p < 0.05$) increased in whole grains 2.7 times higher from 27.77% in the raw to 74.47% in the parboiled.

It was observed that the parboiled rice had significantly higher levels of adulterants (2.25%) which were 3.3 times higher than the raw (0.67%).

4.3 Functional Properties

4.3.1 Swelling Power and Solubility

Swelling is the first stage in the initiation changes in hydration related properties. The swelling power of the raw rice (5.36) was significantly higher ($P < 0.05$) than the parboiled rice (5.06) (Table 4.2). Swelling power has been related to the associative binding within the starch granule, and apparently, the strength and character of the micellar network is related to the amylose content of the starch

4.3.2: Water and Oil Absorption Capacity

The water absorption capacity describes water- association ability under limited water supply. The water absorption of the parboiled rice was significantly higher than that of the raw rice as shown in Table 4.2. The parboiled rice had a higher water absorption capacity of (1.5ml/g) as compared to 1.38ml/g of the raw rice**.** The oil absorption capacity also showed similar trend as water absorption capacity, increasing with parboiling from 1.28 to 1.48ml/g.

Table 4.3: Effect of parboiling on the functional properties of rice

Parameters	Parboiled	Non-parboiled
Swelling power	$5.06\pm0.06_B$	$5.36\pm0.04_A$
Solubility (%)	$3.0.\pm0.00_A$	$3.0\pm0.01_A$
WAC (ml/g)	$1.50\pm0.06_A$	$1.38\pm0.05_B$
OAC (ml/g)	$1.48\pm0.08_A$	$1.28\pm0.08_A$
Bulk Density	$0.88\pm0.02_A$	$0.9\pm0.01_A$
Least Gelation Concentration (%)	$16.33\pm0.58_A$	$10.33\pm0.58_B$

Means of triplicates ± SD followed by different letters within a row is significantly different ($p < 0.05$). WAC – water absorption capacity; OAC – Oil absorption capacity

4.3.3: Bulk Density

Bulk density is a measure of heaviness of a flour sample. From Table 4.3, the raw rice was only marginally higher in bulk density (0.90g/cm^3) than the parboiled rice (0.88 g/cm^3).

4.3.4: Gel Formation

Gelling capacity of parboiled and non-parboiled rice in water at different protein concentration is shown in Table 4.3. The least gelation concentration significantly increased ($p < 0.05$) from 10.33% in raw rice to 16.33% in the parboiled.

4.4: Rice cooking and cooked rice characteristics

4.4.1: Cooking time

The cooking time of the parboiled Degan rice (13.16 minutes) was significantly higher ($P<0.05$) than the raw (11.70 minutes) as indicated in Table 4.4.

Table 4.4: Effect of parboiling on the cooking time of rice

Parameter	Parboiled	Non-parboiled
Cooking time (minutes)	13.16±0.06$_A$	11.70±0.52$_B$

Means of triplicates ± SD followed by different letters within a row is significantly different ($p < 0.05$).

4.4.2: Sensory Analysis

Table 4.5: Sensory evaluation of cooked parboiled and non-parboiled rice (n=22)

Parameter	Parboiled	Non-parboiled
Aroma	4.31±0.30$_A$	3.56±0.35$_B$
Colour	3.67±0.23$_B$	4.26±0.20$_A$
Texture	3.54±0.14$_A$	3.35±0.02$_A$
Stickiness	4.23±0.29$_A$	3.48±0.14$_B$
Taste	4.31±0.24$_A$	3.39±0.17$_B$
Overall acceptability	4.80±0.07$_A$	3.98±0.25$_B$

Means of triplicates ± SD followed by different letters within a row is significantly different ($p < 0.05$).

The results of the sensory assessment showed that the aroma, stickiness and taste of cooked parboiled Degan rice was significantly better preferred to the unparboiled. Whereas parboiled rice scored 4.31, 4.23 and 4.31 respectively for aroma, stickiness and taste the unparboiled rice scored 3.56, 3.48 and 3.39.

CHAPTER FIVE

DISCUSSION

5.1: Survey

5.1.1: Gender, civil status and other activities performed by people involved in rice parboiling

Figure 4.1 showed the gender balance among people involved in rice parboiling interviewed during the survey. All (100%) of those involved in parboiling were female which showed that parboiling, a post-harvest activity in the rice food chain is mainly dominated by females. This is partly due to the fact that within many communities in Ghana, especially in the Northern part of the country where the survey was taken, women cannot own land or farm. They are thus only involved in performing post-production operations, namely harvesting, threshing, drying, parboiling, milling, storage and trade. The preparation of milled rice for consumption, the transformation of milled rice to other products, and the utilization of broken rice, rice bran, rice hulls and husks, and rice straw provide additional employment opportunities to women in the Northern Region of Ghana. In a study examining womens' role in the various stages of rice production in the Tamale Metropolis of Ghana, it was reported that women were predominantly engaged in seed sowing, fertilizer application and harvesting (GIDA, 2006). Parboiling is a vast and important cottage industry in the Northern Regions of Ghana dominated by women who buy and parboil small quantities of paddy on a daily basis. The parboiled rice is then milled locally and sold at nearby markets (GIDA, 2006).

When asked of their marital status, 76.0% of the respondents indicated that they were married with only 4.0% that were single as shown in Figure 4.2. The result implies that majority of them have family members to take care of. They (women) thus do parboiling to generate income for expenses on clothing, housing, education and other social activities.

This is particularly, necessary for the 40.0% of the respondents who indicated they solely obtained their livelihood from parboiling (Figure 4.3). Figure 4.3 showed that parboiling is an important socio-economic activity for women in the Northern Region of Ghana since majority of them depend on it as a source of livelihood. Thus, improving parboiling in the region will enhance the living standard of the rural poor in the communities where rice production is a major economic activity.

5.1.2: Average age of respondents, their level of education and years of experience in rice parboiling

Majority of respondents were within the age range of 40-60 years, representing 56% of the sample size. Only 42% were below this range as shown in Figure 4.4. This meant that women involved in rice parboiling in the Northern Region of Ghana are in their reproductive years and are part of the active work force of Ghana. Experience in rice parboiling ranged from majority 20 years (representing 28% of respondents) of continuous practice to those who had just 1-5 years experience (10% of respondents) as shown in Figure 4.5. More than sixty percent (68%) of respondents had more than 10 years experience in rice parboiling and it may be concluded that almost all the respondents had some experience in the parboiling of rice and that the majority of them had practiced parboiling for several years. It was therefore expected that they would be able to produce good quality parboiled rice.

Results of the survey indicated that 76.0% of respondents had no formal education with only 18.0% with formal education of up to the JSS/middle school level (Figure 4.6). The result also showed that it would be quite difficult for the respondents to read to find information to improve their trade. This is more worrying and has serious implications on the quality of parboiled rice as the process of parboiling is technical and needs to be controlled in order to obtain the required qualities. Roy *et al*. (2011) reported that over-parboiling for example, results in over-opening of the husk components followed by bulging out of the endosperm which initiates surface scouring during milling and the resultant ground particles being lost into the husk and bran. There is therefore the need to provide in-service training to those who are already in the business to raise their status quo on the technicalities involved in rice parboiling. Educating people involved in rice parboiling in the Northern Region of Ghana will enable them produce more quality parboiled rice products thereby raising their profit margin, an outcome which will improve their living standard, especially that of the rural poor.

5.1.3: Milling recovery of parboiled and non-parboiled rice

The survey showed that, the parboiling resulted in higher head rice yield as compared to non-parboiled rice (Table 4-2). Ninety six percent (96.0%) of respondents believed that parboiled rice had very good milling recovery which was confirmed quantititavely in this study. As high as 78.0% of people involved in rice parboiling indicated that unparboiled rice had poor milling quality (Figure 4.7).

Parboiling is used in the Northern Region to reduce breakages during milling and increase the head rice yield (HRY). This is due to relatively much drier climate during the main harvest season than in the southern part of the country. The parboiling process is applied to rice with a preliminary objective of hardening the kernel in order to maximize head rice yield in milling. This improvement is caused by stronger structure of rice starch as a result of gelatinization process (Soponronnarit *et al*., 2006). Saif *et al.* (2004) similarly reported that the increase in length, width and thickness due to parboiling, leads to strengthening of kernel integrity and increase of milling recovery.

When asked to rate the milling recovery in terms of percentages, 76.0% of rice mill operators indicated that the percentage whole grain in milled parboiled rice per bag is between 51.0-60.0% with only 22.0% of respondents indicating that the percentage whole grain in a bag of milled parboiled rice is below this range (Figure 4.8). On the contrary, as high as 68.0% of the mill operators interviewed intimated the percentage broken grains in non-parboiled rice are above 60.0% which was confirmed (Table 4-2).

5.1.4: Cooking characteristics of parboiled and non-parboiled rice

During the survey rice consumers were asked to rate parboiled and non-parboiled rice in terms of their swelling ability and taste. Their responses as shown in Figure 4.9. 74.0% of respondents rated raw (un-parboiled) rice swells as very good as compared to 12.0% who indicated that parboiled rice swells very good. In general, consumers have the opinion that non-parboiled rice swells better than parboiled rice. 84.0% of respondents indicated that the swelling observed in parboiled rice was satisfactory.

Parboiling has obvious impact on the organoleptic proprieties of cooked rice. Kar *et al* (1999) reported that cooked parboiled rice is firmer than non-parboiled rice. De Datta (1986) also reported that, parboiling gelatinises the starch within the rice grains, causing swelling and fusion within the kernel and increasing moisture content. The grains are thus not much able to swell during subsequent cooking but the difference is not enough to curtail the many benefits of parboiling.

5.1.5: Source of foreign material in milled rice

A combination of milled rice sellers and those who parboil rice themselves were asked if consumers complained of foreign materials in their milled rice. More than twenty percent (22.0%) of them indicated that consumers did not complain of foreign materials at all.(Figure 4.10) As to the source of the foreign matter (adulterants) 10% indicated that they were picked during the drying period immediately after parboiling. As high as 44.0% reported that the foreign materials contaminate the paddy during the process of threshing and drying. The result however are some indication that people involved in rice parboiling contribute to ensuring that a pure, foreign material-free rice product is sold to consumers.

5.1.6: Rice parboiling and marketing

5.1.6.1: Where parboiled rice is marketed

The survey showed that majority of those who parboiled their rice (88%) sold it at the nearest market, with only 12.0% selling theirs at the farm-gate (place of parboiling; Figure 4.11). Transporting to the market incurred additional cost, but in most cases was likely to be offset by the relatively higher market price when compared to the price at the farm-gate.

5.1.6.2: Economically active household members who help in full time during parboiling

Seventy two percent of the respondents indicated that, they usually employed the services of 1-5 active household members who helped in full time during rice parboiling (Figure 4.12). The result also showed that, 22.0% of respondents employed the services of between 6-10 people during rice parboiling with only 6.0% employing more than 10 people as shown in figure 4.12 below. The mean number of household members who helped in parboiling was 5.06 (see appendix). The results suggested that parboiling is a family business and likely to be passed on from generation to generation, they however need capacity building on the use of new technology in parboiling

5.1.6.3: Cost of processing a bag of rice

Figure 4.13 outlined the cost of parboiling a bag of rice including the cost of transporting milled parboiled rice to the market place within the Tamale metropolis where the survey was conducted. 39 cases (representing 78.0% of respondents), indicated that they spent between GH¢ 6-10 on a bag of parboiled rice and transported to market. No rice parboiler spent below this range and only 11 (22%) respondents spent above this range. The mean cost of processing a bag of rice of which the cost of parboiling constituted 65% according to this survey was GH¢ 8.33.

5.1.6.4: Selling price per bag (50kg) of whole grains and broken grains rice

The Figure 4.14 showed the selling price per bag of whole grains and broken grains in the Tamale market. As high as 52.0% of the respondents sold a bag (50kg) of whole grains milled rice between GH¢ 51-60 whilst the same quantity of broken rice was mostly sold between GH¢ 30-40.

Obviously, a bag of whole grains had a higher price than a bag of broken grains of the same quantity. The average price for a 50kg bag of milled whole grains rice in the region is GH¢ 54.72 and that of a 50kg bag of milled broken grains rice is GH¢39.20

5.1.6.5: Cost benefit analysis of parboiling in Northern Region

The cost benefit analysis data on parboiling in the Northern Region was obtained from the responses from the survey which was a true reflection of the prevailing market conditions in the region. In the parboiled rice, 80kg paddy yielded 59.52kg milled rice of which 41.52kg and 18.00kg were whole grains and broken grains, respectively. On the contrary, 80kg non-parboiled paddy yielded only 42.27kg milled rice comprising of 20.23kg and 22.04kg whole grains and broken grains, respectively. Taking the average selling price for a 50kg bag of milled whole grains rice in the region to be GH¢ 54.72 and that of a 50kg bag of milled broken grains rice to be, GH¢39.20; then the costs and returns of parboiled rice is shown in (table 4.1). There was a profit margin of GH¢9.72 per bag on parboiled rice but this excluded money paid for family labour. If money paid for family labour is considered, parboiling might be more expensive depending on the number of family labour involved.

5.2: Physico-chemical Properties

Table 4.1 shows the results of data on the physico-chemical properties of both parboiled and raw rice samples. Whereas the moisture content of the raw rice was 9.33%, that of parboiled was 10.33%. Moisture content of the raw rice differed significantly ($p < 0.05$) from the parboiled. According to De Datta (1986) parboiling gelatinises starch within the rice grains, causing swelling and fusion within the kernel and increasing moisture content. Moisture content of rice is known to affect its milling characterisitics. The moisture content of the parboiled rice probably contributed to the milling yield (74%) observed in this study.

The 1000 grain weight of the parboiled rice (18.13g) was significantly higher ($P<0.05$) than the raw (15.60g). The observed increase could be attributable to absorbed moisture during parboiling (Table 4.2).

Rice is parboiled with the objective of hardening the kernel in order to maximize head rice yield in milling. Soaking and steaming processes during parboiling has great influence on milling recovery of parboiled rice. Parboiling significantly increased ($p < 0.05$) the head rice yields by 1.4 times from 52.84% to 74.40%. Parboiling is known to toughen grain and reduce the amount of breakage during milling (Bhattacharya, 1985). During parboiling gelatinization of starch makes grains stronger and tougher improving milling qualities (Soponronnarit *et al*., 2006). This therefore could account for the higher percentage result in the whole grains, which also increased significantly ($p < 0.05$) by 2.7 times from 27.77% in the raw to 74.47% in the parboiled.

It was observed that the parboiled rice had significantly higher levels of adulterants (2.25%) which were 3.3 times higher than the raw (0.67%). The higher levels of adulterants in the parboiled rice could be attributed to poor handling practices during drying. It was observed that the farmers dried their parboiled rice on poor concrete floors and therefore during the collection of the dried parboiled rice they picked up stones in the process. This observation explains why the respondents in the survey reported that parboiled rice has many stones.

5.3 Functional Properties

5.3.1 Swelling Power and Solubility

Swelling is the first stage in the initiation changes in hydration related properties. The swelling power of the raw rice (5.36) was significantly higher ($P < 0.05$) than the parboiled rice (5.06) (Table 4.2). Swelling power has been related to the associative binding within the starch granule, and apparently, the strength and character of the micellar network is related to the amylose content of the starch. The lower the amylose content the higher the swelling power. Since most of the starch in the parboiled rice had been gelatinized, it resulted in a decreased associative binding capacity within the starch. The degree of starch gelatinization is responsible for many of the attributes of parboiled rice (Marshall *et al.*, 1993). During the process of gelatinization, amylose molecules leach out of the micellar network and diffuse into the surrounding aqueous medium outside the granules (Hermansson and Svegmark, 1996). This perhaps resulted in increased solubility of the parboiled rice. Swelling power is an important property for noodle production. Since the raw rice had higher swelling power it would be a better ingredient for noodle production than raw rice.

As regards their solubility both the raw and parboiled rice were similar and varied between 2.0% and 3.0% for raw and parboiled rice, respectively.

5.3.2: Water and Oil Absorption Capacity

The water absorption capacity describes water- association ability under limited water supply. The water absorption of the parboiled rice was significantly higher than that of the raw rice as shown in Table 4.2. Mustapha (1979) in his study on physico-chemical qualities of rice stated that parboiled rice has higher water absorption, which may be as a result of the steaming pressure during parboiling which in turn affects starch gelatinisation. The higher water absorption capacity of the parboiled rice (1.5ml/g) compared to 1.38ml/g of the raw could be attributable to gelatinization of starch resulting in exposure of subunits of hydrophyllic protein in rice, and therefore higher moisture absorption (Narayana and Narasinga Rao, 1984).

The results showed that heat denaturation improved the water holding capacity of starch within samples (Table 4.3). The higher water absorption of the parboiled rice suggested it would perform better as ingredient for infant food than raw rice.

Oil absorption capacity also showed similar trend as WAC, increasing with parboiling from 1.28 to 1.48ml/g. The higher oil absorption capacity of the parboiled could be attributable to perhaps exposure of lipophillic and non-polar amino acids (Kinsella, 1976). Parboiled rice could therefore be more useful for carrying flavour-enhancing oils than the raw rice and could therefore be suitable for cakes and sausage production.

5.3.3: Bulk Density

Bulk density is a measure of heaviness of a flour sample. The raw rice was only marginally higher in bulk density (0.90g/cm^3) than the parboiled rice (0.88 g/cm^3).

5.3.4: Gel Formation

Gelling capacity of parboiled and non-parboiled rice in water at different protein concentration is shown in Table 4.3. The least gelation concentration significantly increased ($p < 0.05$) from 10.33% in raw rice to 16.33% in the parboiled. Gelation involves the swelling of starch granules on heating, the low gelation concentration of non-parboiled rice could be attributed to higher level of total available carbohydrate than in the parboiled rice. The gelling capacity is attributed to denaturation, aggregation and thermal degradation of starch. According to Schmidt (2010), considerably high protein concentration is usually required for the gelation of globular proteins. Hermansson (1996,) reported that Protein gel structure becomes increasingly fine and continuous with the gel possessing an improved capacity to retain moisture. Since the parboiled rice had the highest least gelation concentration it may not be a good gelling agent as compared to raw rice.

5.4: Rice cooking and cooked rice characteristics

5.4.1: Cooking time

The cooking time of the parboiled Degan rice (13.16 minutes) was significantly higher ($P<0.05$) than the raw (11.70 minutes) as indicated in Table 4.4. This observation was similar to what Saeed *et al.* (2011) observed in milled Super Basmati rice. Cooking time depends not only on parboiling process, but also on rice variety and storage time (Hogan, 1963). It is generally understood that cooked parboiled rice is harder and less sticky than raw cooked rice (Islam *et al.*, 2001). Hardness value is greatly affected by parboiling condition such as starch gelatinization and amylose content. Hardness is the most important physical property of parboiled rice among all the physical properties. Generally, harder rice requires longer time to cook under the same conditions. The higher cooking time for parboiled rice is indicative that it would require more energy and time for cooking which present economic disadvantage.

5.4.2: Sensory Analysis

The results of the sensory assessment showed that the aroma, stickiness and taste of cooked parboiled Degan rice were significantly better preferred to the unparboiled. Whereas parboiled rice scored 4.31, 4.23 and 4.31 respectively for aroma, stickiness and taste the unparboiled rice scored 3.56, 3.48 and 3.39. This was not surprising as Kar *et al* (1999) had reported that parboiling has obvious impact on the organoleptic proprieties of cooked rice.

On the other hand the colour of the unparboiled was perceived to be more acceptable (4.26) than the unparboiled (3.67). The colour of the parboiled was darker than the unparboiled. Panel preferred the lighter colours of unparboiled rice. The degree of colour change has been reported to be influenced by soaking temperature, heating duration, and heating and drying temperature (Jayanarayanan 1965; Johnson, 1965); Bhattacharya and Subba Rao, 1966; Pillaiyar and Mohandoss, 1981). Colour change during parboiling of rice has been attributed to non-enzymatic browning of the Maillard type (Houston et al., 1956; Bhattacharya and Subba Rao, 1966).

The texture of both parboiled and raw Degan rice was perceived to be similar (3.67-4.26).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1: Conclusion

This study has shown that there is a high preference for parboiled rice in the Northern Region. Parboiling was able to significantly improve the physical properties as well as head grain yield, whole grain water absorption and least gelation concentration of Degan rice. The high percentage of stones in parboiled rice in the Northern Region of Ghana gives some indications that people involved in rice parboiling have some part to play in ensuring that a pure, foreign material-free rice product is sold to consumers. Appropriate postharvest handling practices should be adopted to ensure superior quality free from adulterants.

The cost benefit analysis of parboiled rice in the Northern Region of Ghana also showed that if parboiling is done well it can help improve the financial well being of farmers.

The number of years the farmers have got in parboiling also indicates that they have experience in parboiling hence a quality product (rice) can be produced. It was also realised that most of the farmers are in their productive ages, this means that they can contribute greatly to the working force of the country.

6.2: Recommendation

Improved methods of drying of parboiled rice should be adopted by producers for superior quality parboiled rice devoid of adulterants

Handling of paddy in the production chain should be done with care in order to avoid contamination (adulterants)

Good farming practices like rogueing,weeding,threshing on tarpaulins as well as cemented floors should be adopted by farmers,inorder that clean product will be produced during parboiling.

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APPENDIX

A. Questionnaire for Survey

1. Identification

NO		Code	Response
1.1	Questionnaire number	QUESNUM	
1.2	Date (dd/mm/yy)	DATE	
1.3	Village or Town	PLACE	
1.4	District	DISTRICT	
1.5	Region	REGION	
1.6	Country	CNTRY	
1.7	Name of enumerator	NAMENUM	
1.8	Name of respondent	NAMERESP	

2. Demographic Background Of Respondent

NO		Code	Response
2.1	Age of farmer/respondents	AGE	
2.2	Sex of respondents 1= Male 2= Female	SEX	
2.3	Ethnicity 1= Akan 2= Ewe 3= Dagomba 4= Gonja 5= Konkomba 6= Nanumba 7= Other (*specify*)	ETHNY	
2.4	Residence status 1= indigene 2= permanent settler 3= Migrant (temporary residence)	RESTAT	
2.5	Type of education received 1= Formal 2= Informal	EDUC	
2.6	Years of schooling	SCHOOL	
2.7	Level of Education 1= Primary 2= JHS/Middle 3= Secondary 4= Vocational/Technical 5= Tertiary 6= Other	LEVLEDUC	
2.8	Marital Status 1= Single 2= Married 3= Divorced	MSTATUS	
2.9	Household size	HHSZE	
2.10	Number of economically active household members, (> 16 and < 65 years old), including the household head who help full time during parboiling.	FARMLAB	
2.11	How many years have you been into rice parboiling	FRMEXP	
2.12	Apart from rice parboiling, do you do any other activity 1=yes 2=no	OTHERACT	
2.13	If yes which of the following do you engage in Casual Labour.=1 Self-employed=2 Skilled labour =3 Student.=4 Salaried employment .=5 Petty trading .=6	YESOTHAC	

3. Rice variety milling characteristics

How does the variety you work on express these milling characteristics?
Importance of characteristic
1= very good
2=good
3=poor

No.	Characteristics	Rating	
		Raw	Parboiled
3.1	Milling recovery		
3.2	Breakage during milling		
3.3	Cooking		
3.4	Smell (aroma)		
3.5	Swelling		
3.6	Taste		

4. Rice Parboiling and Marketing

No		Code	Response Raw	Response Parboiled
4.1	How do you sell your rice? 1= farm gate 2= Through the nearest market 3= Others	SELLRICE		
4.2	What is the percentage whole grain/bag after milling? 1=below 40% 2=40-50% 3=51-60% 4= above 61%	%WHOLEMIL		
4.3	What is the percentage broken rice per bag after milling? 1=below 50% 2=50-60% 3=61-70% 4= above 70%	%BROKENMIL		
4.4	Number of people involved in parboiling a bag of rice 1=1-2 people, 2=3-4 people, 3=5-6 people, 4= 7 and above	NUMPARB		
4.5	Cost involved in parboiling rice per bag 1= GH¢ 1-5 2= GH¢ 6-10 3= GH¢11-15 4= above GH¢ 15	COSTPARB		
4.6	Do customers complain of foreign materials in milled rice? 1= Yes, 2= No	FOGNM		
4.7	If yes to 4.6, when do these foreign materials get to the rice 1= harvesting, 2=threshing and drying, 3= during parboiling, 4= milling	SOURCEFOGNM		
4.8	What are the main foreign materials encountered?	MAINFOGNM		
			WHOLE	BROKEN
4.9	How much did you sell a bag (50kg) of milled rice? 1= GH¢30-40, 2= GH¢ 41-45, 3= GH¢ 46-50, 4= GH¢ 51-60, 60	PRICEMIL		

B. Frequency Tables

Age of respondents

	Frequency	Percent	Cumulative Percent
1-19	1	2.0	2.0
20-39	20	40.0	42.0
40-60	28	56.0	98.0
> 60	1	2.0	100.0
Total	50	100.0	

Gender

	Frequency	Percent	Cumulative Percent
Male	0	0.0	0.0
Female	50	100.0	100.0
Total	50	100.0	

Level of Education

	Frequency	Percent	Cumulative Percent
No formal Edu.	38	76.0	76.0
Primary	3	6.0	82.0
JSS/Middle Sch.	9	18.0	100.0
Total	50	100.0	

Marital status

	Frequency	Percent	Cumulative Percent
Single	2	4.0	4.0
Married	38	76.0	80.0
Divorced	10	20.0	100.0
Total	50	100.0	

Economically active household members

	Frequency	Percent	Cumulative Percent
2	7	14.0	14.0
3	13	26.0	40.0
4	7	14.0	54.0
5	9	18.0	72.0
6	6	12.0	84.0
8	3	6.0	90.0
10	2	4.0	94.0
13	1	2.0	96.0
16	1	2.0	98.0
18	1	2.0	100.0
Total	50	100.0	

Experience in parboiling

	Frequency	Percent	Cumulative Percent
1-5	5	10.0	10.0
6-10	11	22.0	32.0
11-15	12	24.0	56.0
16-20	8	16.0	72.0
> 20	14	28.0	100.0
Total	50	100.0	

Other activities performed by parboilers

	Frequency	Percent	Cumulative Percent
None	19	38.0	38.0
Casual labour	3	6.0	44.0
Self-employed	3	6.0	50.0
Skilled labour	4	8.0	58.0
Student	0	0.0	58.0
Salaried-employed	2	4.0	62.0
Petty trading	19	38.0	100.0
Total	50	100.0	

Rating: milling recovery of non-parboiled rice

	Frequency	Percent	Cumulative Percent
Very good	0	0.0	0.0
Good	11	22.0	22.0
Poor	39	78.0	100.0
Total	50	100.0	

Rating: milling recovery of parboiled rice

	Frequency	Percent	Cumulative Percent
Very good	48	96.0	96.0
Good	2	4.0	100.0
Poor	0	0.0	100.0
Total	50	100.0	

Rating: swelling of non-parboiled rice

	Frequency	Percent	Cumulative Percent
Very good	37	74.0	74.0
Good	13	26.0	100.0
Poor	0	0.0	100.0
Total	50	100.0	

Rating: swelling of parboiled rice

	Frequency	Percent	Cumulative Percent
Very good	6	12.0	12.0
Good	42	84.0	96.0
Poor	2	4.0	100.0
Total	50	100.0	

Rating: taste of non-parboiled rice

	Frequency	Percent	Cumulative Percent
Very good	14	28.0	28.0
Good	35	70.0	98.0
Poor	1	2.0	100.0
Total	50	100.0	

Rating: taste of parboiled rice

	Frequency	Percent	Cumulative Percent
Very good	16	32.0	32.0
Good	32	64.0	96.0
Poor	2	4.0	100.0
Total	50	100.0	

Preferred marked for milled rice

	Frequency	Percent	Cumulative Percent
Farm-gate	6	12.0	12.0
Nearest market	44	88.0	100.0
Total	50	100.0	

Percent whole grains in non-parboiled rice after milling

%	Frequency	Percent	Cumulative Percent
<50	33	66.0	66.0
50-60	3	6.0	72.0
61-70	8	16.0	88.0
>70	6	12.0	100.0
Total	50	100.0	

Percent whole grains in parboiled rice after milling

	Frequency	Percent	Cumulative Percent
<50	4	8.0	8.0
50-60	7	14.0	22.0
61-70	38	76.0	98.0
>70	1	2.0	100.0
Total	50	100.0	

Cost of processing per bag

GH¢	Frequency	Percent	Cumulative Percent
1-5	0	0.0	0.0
6-10	39	78.0	78.0
11-15	11	22.0	100.0
Total	50	100.0	

Percent broken grains in non-parboiled rice after milling

	Frequency	Percent	Cumulative Percent
<50	8	16.0	16.0
50-60	4	8.0	24.0
61-70	4	8.0	32.0
>70	34	68.0	100.0
Total	50	100.0	

Percent broken grains in parboiled rice after milling

	Frequency	Percent	Cumulative Percent
<50	48	96.0	96.0
50-60	1	2.0	98.0
61-70	1	2.0	100.0
>70	0	0.0	100.0
Total	50	100.0	

Source of foreign material in milled rice

	Frequency	Percent	Cumulative Percent
None	12	24.0	24.0
Threshing/drying	6	12.0	36.0
Harvesting	23	46.0	82.0
During parboiling	5	10.0	92.0
At milling	4	8.0	100.0
Total	50	100.0	

Selling price per bag (50g) of whole grains

GH¢	Frequency	Percent	Cumulative Percent
30-40	0	0.0	0.0
41-45	26	52.0	52.0
46-50	1	2.0	54.0
51-60	23	46.0	100.0
Total	50	100.0	

Selling price per bag (50g) of broken grains

GH¢	Frequency	Percent	Cumulative Percent
30-40	44	88.0	88.0
41-45	6	12.0	100.0
46-50	0	0.0	0.0
51-60	0	0.0	0.0
Total	50	100.0	

C. Anova Tables

Analysis of Variance table for bulk density

Source	DF	SS	MS	F	P
TRT	1	0.00107	0.00107	5.82	0.0734
Error	4	0.00073	0.00018		
Total	5	0.00180			
Grand Mean:	0.8900	CV: 1.52			

Analysis of Variance Table for least gelation capacity

Source	DF	SS	MS	F	P
TRT	1	54.0000	54.0000	162.00	0.0002
Error	4	1.3333	0.3333		
Total	5	55.3333			
Grand Mean:	13.333	CV: 4.33			

Analysis of Variance Table for OAC

Source	**DF**	**SS**	**MS**	**F**	**P**
TRT	1	0.06000	0.06000	10.29	0.0327
Error	4	0.02333	0.00583		
Total	5	0.08333			
Grand Mean 1.3833	CV 5.52				

Analysis of Variance Table for WAC

Source	**DF**	**SS**	**MS**	**F**	**P**
TRT	1	0.03375	0.03375	13.50	0.0213
Error	4	0.01000	0.00250		
Total	5	0.04375			
Grand Mean 1.4250	CV 3.51				

Analysis of Variance Table for solubility

Source	**DF**	**SS**	**MS**	**F**	**P**
TRT	1	6.667E-05	6.667E-05	1.00	0.3739
Error	4	2.667E-04	6.667E-05		
Total	5	3.333E-04			
Grand Mean	0.0233	CV 34.99			

Analysis of Variance Table for swelling power

Source	**DF**	**SS**	**MS**	**F**	**P**
TRT	1	0.13802	0.13802	51.76	0.0020
Error	4	0.01067	0.00267		
Total	5	0.14868			
Grand Mean	5.2083	CV 0.99			

Analysis of Variance Table for %Adulterants

Source	DF	SS	MS	F	P
TRT	1	3.76042	3.76042	110.06	0.0005
Error	4	0.13667	0.03417		
Total	5	3.89708			
Grand Mean: 1.4583		CV: 12.67			

Analysis of Variance Table for Head rice yield

Source	DF	SS	MS	F	P
TRT	1	696.819	696.819	5668.27	0.0000
Error	4	0.492	0.123		
Total	5	697.311			
Grand Mean: 63.620		CV: 0.55			

Analysis of Variance Table for %Moisture Content

Source	DF	SS	MS	F	P
TRT	1	3.37500	3.37500	5.79	0.0339
Error	4	2.33333	0.58333		
Total	5	5.70833			
Grand Mean: 10.083		CV: 7.57			

Analysis of Variance Table for Weight of 1000 grains

Source	DF	SS	MS	F	P
TRT	1	9.6267	9.62667	32.45	0.0047
Error	4	1.1867	0.29667		
Total	5	10.8133			
Grand Mean: 16.867		CV: 3.23			

Analysis of Variance Table for % whole grains

Source	DF	SS	MS	F	P
TRT	1	3271.34	3271.34	285.28	0.0001
Error	4	45.87	11.47		
Total	5	3317.20			
Grand Mean: 51.117		CV: 6.62			

Analysis of Variance Table for Aroma

Source	DF	SS	MS	F	P
trt	1	0.84375	0.84375	7.83	0.0489
Error	4	0.43113	0.10778		
Total	5	1.27488			
Grand Mean: 3.9317		CV: 8.35			

Analysis of Variance Table for Colour

Source	DF	SS	MS	F	P
trt	1	0.52215	0.52215	11.14	0.0289
Error	4	0.18753	0.04688		
Total	5	0.70968			
Grand Mean: 3.9617			CV: 5.47		

Analysis of Variance Table for Cooking time

Source	DF	SS	MS	F	P
trt	1	9.05282	9.05282	66.63	0.0012
Error	4	0.54347	0.13587		
Total	5	9.59628			
Grand Mean: 10.932			CV: 3.37		

Analysis of Variance Table for Overall acceptability

Source	DF	SS	MS	F	P
trt	1	1.00860	1.00860	30.35	0.0053
Error	4	0.13293	0.03323		
Total	5	1.14153			
Grand Mean: 4.3933			CV: 4.15		

Analysis of Variance Table for Stickiness

Source	DF	SS	MS	F	P
trt	1	0.83627	0.83627	16.38	0.0155
Error	4	0.20427	0.05107		
Total	5	1.04053			
Grand Mean: 3.8567			CV: 5.86		

Analysis of Variance Table for Taste

Source	DF	SS	MS	F	P
trt	1	1.26960	1.26960	28.19	0.0060
Error	4	0.18013	0.04503		
Total	5	1.44973			
Grand Mean: 3.8533			CV: 5.51		

Analysis of Variance Table for Texture

Source	DF	SS	MS	F	P
trt	1	0.52215	0.52215	50.53	0.0021
Error	4	0.04133	0.01033		
Total	5	0.56348			
Grand Mean: 3.6417			CV: 2.79		